THE HAWAIIAN
PLANTERS' RECORD

Vol. XL SECOND QUARTER, 1936 No. 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

A Suggested Scheme of Irrigation Control Using the Day-Degree System:

How to regulate irrigation from season to season has always been a problem. This article suggests that weather observations may well form the basis of a satisfactory control scheme.

Studies in Experimental Technique:

The search for a more nearly perfect experimental technique for field tests continues. Arguments for and against the practice of discarding border rows are usually decided by the practical consideration of whether or not these outer rows can be eliminated at harvest without the introduction of a more serious error caused by attempts to separate heavy tonnage cane from the inner rows. Arguments for and against a random vs. a regular series arrangement of the plots on the test area have usually been decided in favor of the experimenter's preference.

We now offer a balanced block arrangement of treatments that appears to have considerable merit, in that it definitely reduces the amount of border effect between treatments, and it makes allowance for any definitely natural "fertility slope" that may exist within the test area. Furthermore, the more accurate yield data secured from this arrangement are suitable to statistical interpretation by the analysis of variance, which greatly reduces the experimental error and makes for a more valid estimate of the effect produced by the treatments included in the experiment.

POJ 2878 Cane in the Factory:

Comments are given on POJ 2878 cane from the factory standpoint covering the crops of 1933, 1934 and 1935. These crops represent the periods in which this variety was ground in any appreciable quantity. This cane has caused clarification difficulties at various factories from time to time. A light sulfitation of mixed juice at a few factories having acute difficulties has solved the problem. The manufacture of raw sugar and its refining qualities appear to be no different than

that from other varieties, providing the clarification has been satisfactory. There is some evidence that the steam generating quality of the bagasse is poorer. The fiber content of this cane and, therefore, the percentage of bagasse appear to be lower than that of most of our other canes. These qualities may possibly be accounted for in that this cane matures in several months less time than the standard varieties.

Utilization of Molasses:

The beef cattle industry in these Islands has been well developed as to the ranges and the breeding of the cattle. The full hereditary possibilities of these well-bred animals in quality beef production is not realized because they are not "finished" on concentrated feeds. Practically all of the good beef is now imported from the Mainland.

The feeding value of molasses and bagasse is discussed, and suggestions made for the development of beef production in the Islands.

The Third International Congress of Soil Science:

A discussion is presented which bears upon the proceedings of the Congress and upon matters relevant to soil chemistry as they developed at informal gatherings of delegates.

About four hundred persons from sixty countries attended the sessions of the Congress which were held at Oxford University, England, in the late summer of 1935.

Absorption of Essential Chemical Elements by Segregated Roots of Sugar Cane:

Normal cane growth is reported in experiments wherein nine essential elements were separately absorbed by nine isolated roots. The dissimilarity of the roots in the several solutions, particularly the superior root development in the solution containing calcium, is a matter of theoretical interest. Experiments are cited which demonstrate that a part of the growth response of Sudan grass in certain soils to large applications of superphosphate is due to the calcium constituents of the fertilizer. Both phosphorus and calcium augment the resistance of cane to *Pythium* root rot.

Cane Growth Studies:

Numerous studies have been made of the measurable effects of different soil types, different cane varieties, and different levels of fertilization upon cane and sugar yields and juice quality. To these studies we now add another issue which offers rather convincing evidence that even the relatively small differences in climate that exist in our cultivated sugar cane areas may dominate these more obvious factors of soil, variety and fertilizer. This should arouse further interest in efforts to regulate field procedures and practices so as to take the fullest advantage of the climate that is given us.

Rat Control Investigations at The Lihue Plantation Company, Ltd.:

Rat damage to sugar cane on the island of Kauai is probably greater than on any other island in the Territory. The extent of the problem at The Lihue Plantation Company, Ltd., is given. The large and voracious species of rat, *Rattus norvegicus,* is apparently responsible for all of the damage and is the most difficult of all of the species in Hawaii to control. The standard poison bait used during the past seven or eight years on most of the plantations has not given satisfactory results on Kauai, Lanai, and, to some extent, on the other islands. Recent studies have resulted in an improved bait which contains a higher concentration of thallium sulphate per unit of grain. Rolled barley or rolled oats has also been found to be much superior to whole wheat as bait material. Thomas G. Eckart of The Lihue Plantation Company, Ltd., has gone a step further in the improvement of baits by adding certain aromatic vegetable oils separately to the grain and paper wrapper. The results of many field tests are given which show definite advances in rodent control through the use of alluring oils in particular ways.

Yams:

Today the question of diversified agriculture is a live subject with the plantations. In this article a food crop that plays an important part in the domestic economy of many tropical countries is presented for consideration in this connection.

Standard Methods for Measuring Primary and Total Combustion Volumes in Mill Boilers, Also for Measuring Mill Roller Openings:

The methods adopted as official by the Association of Hawaiian Sugar Technologists and used by the factories in preparing schedules for the Annual Synopsis of Mill Data are presented.

A Suggested Scheme of Irrigation Control Using the Day-Degree System

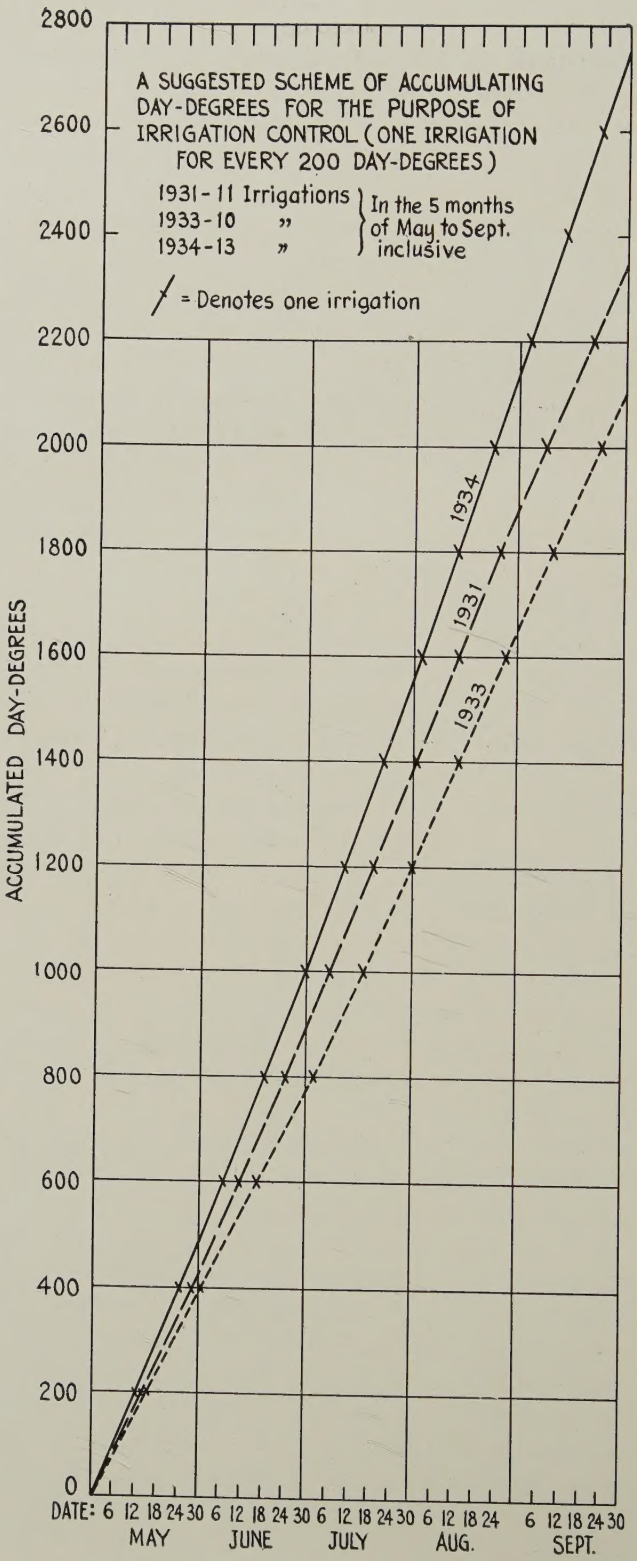
By U. K. Das

One of the chief objectives of irrigation control is to regulate the distribution of water from season to season so as to provide for the changing demands of the cane plant. In most places such control depends on the observations and the past experience of the irrigation overseer. In recent years, however, some plantations have been developing a scheme of irrigation control based on actual soil moisture determinations. It is the purpose of this paper to indicate that in our day-degree system we may have a satisfactory and convenient guide to the seasonal demands of the cane plant.

To start with we shall assume that the seasonal differences in the water requirements of the cane plant are due, largely at any rate, to the differences in the conditions of light and heat. If we could measure the amount of light and heat that affect cane growth, then we could regulate our water distribution accordingly. In our past studies it has been shown that in our "day-degree" we have a very satisfactory index of the conditions of warmth (and probably, light associated with it). Would it not, then, be reasonable to think that we may obtain a satisfactory control of irrigation if we always maintain a definite relation between the amount of water and the growth-promoting factors as measured by the day-degree?

How can we do that in practice? If we have growth measurement data accumulated over a series of years, then, from these data we can select a group of months which have been excellent for growth. We may now reasonably assume that in these months there was sufficient water applied to the cane. Therefore, from the relevant data we can determine the relation between the day-degrees and the percentage of area irrigated in those months. In the case of one plantation, the data of which we were permitted to study, we found the general relation to be about one round of irrigation or hundred per cent of the area irrigated per two hundred day-degrees. (Where cane growth data are lacking such a relationship as the above may be tentatively based on personal experience.)

Having established, let us say, that two hundred day-degrees require one irrigation, we can accumulate the day-degrees from day to day and order one round of irrigation whenever the accumulating sum, since the last irrigation, reaches the two hundred mark. In fact we shall be able to foretell the irrigation needs a few days ahead by studying the trend of the curves if we are plotting the day-degrees on a graph. The accompanying figure shows the progress of the day-degrees on one of our irrigated plantations for the years 1931, 1933 and 1934, and the irrigation rounds that would be called for if we were to give one round for every two hundred day-degrees. Whereas 1933 required only ten irrigations from May to September, 1931 required eleven, and 1934 thirteen for the same period of time. In other words, if we were to maintain a constant relationship between water and effective warmth, then we would have had to apply thirty per cent more water in 1934 than in 1933.


A SUGGESTED SCHEME OF ACCUMULATING DAY-DEGREES FOR THE PURPOSE OF IRRIGATION CONTROL (ONE IRRIGATION FOR EVERY 200 DAY-DEGREES)
1931 - 11 Irrigations
1933 - 10 "
1934 - 13 "
In the 5 months of May to Sept. inclusive
= Denotes one irrigation
ACCUMULATED DAY-DEGREES
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1934
1931
1933
DATE: 6 12 18 24 30 6 12 18 24 30 6 12 18 24 30 6 12 18 24 6 12 18 24 30
MAY
JUNE
JULY
AUG.
SEPT.

A scheme like the above should be looked upon as we do a "basic fertilizer policy;" in other words, deviations from the scheme will be in order whenever experience indicates such to be necessary. Thus we may find that in very young cane we need to apply less than one round for X day-degrees (X may be two hundred or any other value established for the locality), whereas in old cane more than one round is required. Again, similar adjustments may have to be made in the case of heavy and of porous soils—the basic scheme being to apply on the average the same amount of water for equal amounts of effective warmth.

How to adjust for rainfall? In the arid or semi-arid districts like Waianae or Ewa an inch of rainfall may be considered as equal to one-tenth of an irrigation (i. e., ten per cent of the area irrigated). This value may be somewhat different in different places. However, once we have decided from experimental or observational data what value to give to rainfall, we can take that into account in determining when to apply the next irrigation. In general it may be advisable to underestimate rather than overestimate the value of scattered showers.

The above scheme is offered only as a suggestion. The method appears so simple and yet so full of possibilities that it may be worthwhile to set up experiments comparing the plantation practice of irrigation control with the method of control here suggested. It may be advisable to try several ratios—say one round for every 150, 200, or 250 day-degrees, before deciding which is the best under the particular conditions. Even if the scheme be found on experimentation to lack the precision of some of the more elaborate methods, it may provide a control satisfactory enough for practical purposes.

Studies in Experimental Technique

THE BALANCED BLOCK ARRANGEMENT OF TREATMENTS

By R. J. Borden

The statistician who is not also an agronomist usually insists that a valid estimate of the error in a field experiment can only be obtained when the replicates are distributed *at random* on the test grounds. He is likely to look askance at any plot arrangement that appears, on paper, to be regular or systematic. Some agronomists, however, are inclined to feel that a balanced arrangement that is based somewhat on the order of Beaven's "Half-drill strip" plan, i. e., A B B A A B, etc., or an intelligently planned placement of the treatments that are to be compared, may not be entirely wrong, and may in fact have features that are extremely worthwhile.

We fully recognize the value of the probable error concept, in securing the valid estimate of error we desire in order to demonstrate that some differential treatment which we have applied has affected the yields, and to measure the extent of such treatment effect. We recognize that this probable error concept depends upon unbiased or random sampling and a normal frequency distribution, and that the probable error value which is calculated for the relatively few replicates that we can install in field tests is only an estimate of the true probable error. We have no objection to random arrangements as usually advocated but we are not entirely convinced that they are necessary, and we have a feeling that a balanced, definitely planned arrangement may have some real advantage.

Our studies of many hundred field experiments with sugar cane, where the replicated plots have been laid down in a regular series arrangement, as A B C D A B C D A B etc., have not demonstrated the existence of any continuous fertility gradient which has significantly affected the yields obtained and caused an erroneous interpretation of the treatment effect. Short gradients of fertility have occasionally been found within the test areas, and so we have sometimes laid down the replicated plots in two columns of plots, and have reversed the series arrangement in these adjacent columns so as to take care of this possible occurrence, e. g.,

A B C D A B C D A etc.

D C B A D C B A D etc.

It seems quite evident that the larger part of our sugar cane areas are characterized by "spotty" fertility differences rather than by any regular "fertility slope." We have harvested many so-called "blank tests" wherein all plots had received a similar treatment, and the nature of the yields secured has convinced us that fertility differences exist purely at random in our cane field. Thus it is our belief that the randomness which is desired for a true estimate of the experimental error is actually obtained when the first plot of our experiment is assigned its location in the field, and that the spotty nature of our soil fertility gives still further randomness to the plots which follow. Thus what may appear to be a systematic or regular arrange-

ment of plots on paper, is actually a random arrangement on the soil, and no additional efforts to randomize their location can afford anything more than personal satisfaction. If this view is sound then we can proceed with an intelligent placement of the treatments that are to be compared.

The majority of the field experiments which are concerned with problems of fertilization for sugar cane, are designed to determine the optimum amount of nitrogen, of phosphoric acid, or of potash, for areas that are found to be deficient in these plant foods. Hence in these "amounts" tests, we are interested not only in determining that there has been a treatment effect on the yields, but also in determining the significance that can be attached to the amount of yield difference which is the effect of each successive increment of the plant food supplied. For instance, we may be interested in ascertaining whether an application of 150 pounds of nitrogen will be likely to give us a real sugar-tonnage gain over 100 pounds, and whether 200 pounds will give us a still further gain over 150 pounds; we shall not be particularly concerned with the gain of 200 pounds over 100 pounds, unless it is a definite gain over 150 pounds too. Thus we may plan an arrangement of treatments in such a way that those comparisons we most desire are made on closely adjacent plots which our "blank test" data indicate are more apt to be alike than plots which are separated.

The real value of a definitely planned assignment of plots comes from its possibilities in reducing the "border effect" between adjacent plots carrying different treatments. This border effect has been recognized and variously dealt with by all who have carried on field tests, and it is known that its magnitude increases as the adjacent treatments are made more widely different. Hence, if the adjacent plots in a field test are given the minimum possible difference in treatment, we shall go a long way towards reducing the border effect to a minimum.

Our attempts to eliminate border effect in experiments with sugar cane by cutting out the outer row of adjacent plots and discarding this cane, are quite apt to introduce even greater errors than we are trying to get rid of. In experiments which have a heavy tangled mass of cane stalks at harvest, the difficulty with making a single clean separation of cane between plots is well known, and if two separations must be made in order to discard the outside row of each plot, the error of separation is apt to be doubled. Thus any plan which will reduce the border effect to a point where it will be unnecessary to cut out and discard the cane of the border rows needs our thoughtful consideration.

On the assumption that our reasoning is sound, we have proposed and encouraged the use of a balanced block arrangement of treatments for field experiments that are concerned with issues of fertilization. The experimental area is divided into blocks, and each block is of sufficient size to include a single plot of each treatment. The blocks need not all be of the same size, but it is desirable to have the plots in a single block as near alike as possible in number and length of lines, topography, exposure, soil depth, drainage, stand of cane, etc. The relative position of the blocks with respect to one another is immaterial, and where the topography is irregular, they may be separated by areas of "crop cane." Soil and crop *uniformity within any one block* are the primary considerations. Hence we may make use of a plan that does not necessitate our having an area of several acres of uniform soil type and topography, and it becomes much simpler to find acceptable places for our experiments.

KAHUKU PLANTATION CO.

EXP. 56AN, 1936 CROP

POJ 2878 - First ratoons in thirty 9-line plots in ten Blocks.
Yields as T.S.A. @ 15 months.

Plot No.	30	29	28	27	26	25	24	23	22
Treatment	A	X	B	B	X	A	A	X	B
T.S.A.	3.8	5.0	4.8	4.8	5.7	4.7	5.2	6.7	6.2
Plot No.	21	20	19	18	17	16	15	14	13
Treatment	B	X	A	A	X	B	B	X	A
T.S.A.	6.0	6.4	5.7	4.9	5.6	6.0	6.5	6.0	6.3
Plot No.	12	11	10	9	8	7
Treatment	B	X	A	A	X	B
T.S.A.	7.4	6.9	6.3	5.9	6.4	6.1
Plot No.	6	5	4	3	2	1
Treatment	A	X	B	B	X	A
T.S.A.	5.5	6.4	6.1	5.4	6.2	Lost * Est. @ 5.1

* Estimated by method of Allan and Wishart

A deliberate plan is made on paper, and each treatment is assigned a place in each block, the objective being to place the treatments in such a way that the minimum possible border effect will ensue. This idea is carried still farther by reversing the order of plots in the adjacent blocks, so that there will be no border effect between many of the plots on the test area. This reversal of plot assignments in adjoining blocks also has the advantage of providing a balanced arrangement in case there should be a pronounced fertility slope.

After the crop has been grown and harvested, the yields that are obtained may be examined by Fisher's "Analysis of Variance" in order to determine whether there has been a definite effect of treatment, and if there has been, then to measure the significance of the amounts of difference that were found between the differential treatments given.

We present in the accompanying figure a plan of one of an "Amounts of Nitrogen" experiment, laid out according to our balanced block arrangement, which has now been harvested. The features which we have discussed are apparent.

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DATA TO ACCOMPANY ILLUSTRATION ON PAGE 115

Plots	Plan of Fertilization—(Pounds Nitrogen Per Acre) Dec.	Feb.	April	Total	Results: Avg. Yield T. S. A.
A	72	28	0	100	5.34
X	72	78	0	150	6.13
B	72	78	50	200	5.93

An examination of these yield data, by the analysis of variance, quite clearly shows that there has been an effect of treatment, and indicates that an amount of difference between the treatment averages which is greater than .3 ton of sugar would be significant. Thus it is apparent that the experiment has shown a reliable gain for an application of 150 pounds of nitrogen over 100 pounds but that there was no further gain for the 200 pounds application.

POJ 2878 Cane in the Factory

By W. L. McCleery

In the Experiment Station Director's Monthly Report issued December 10, 1933, the writer presented a short summary of the qualities of POJ 2878 cane from the factory standpoint. The crop of 1933 had just been completed and the Synopsis data for that year showed that this variety comprised over one per cent of the crop harvested at nine factories.

Clarification difficulties had been encountered during 1933 at several factories when grinding POJ 2878 cane and considerable concern was felt in various quarters as to the probable refining qualities of the sugar produced from this variety. Early in the 1934 grinding season, requests were sent to the plantations that were to harvest POJ 2878 cane, asking that samples of sugars be sent us from POJ 2878 and from other (standard) varieties. The request for these samples was made in order that we might obtain information on the filtrability and color characteristics of sugar from POJ 2878 in comparison with those of sugars from the standard varieties and for possible further study.

Later in the 1934 season, as soon as the few factories having any considerable amounts of this cane began grinding it unmixed with other canes, it was apparent that one of the major factors influencing the refining quality would be the quality of the clarification and if the clarification were satisfactory, the sugar refining qualities would follow closely those of other varieties. This has since been fully confirmed. We had long recognized that there was a marked correlation between the clarity of the juice sent to the evaporators and the characteristics of filtrability, original color and crystal color of the sugar.

The clarification difficulties with POJ 2878 cane were much greater than were expected when this variety was originally planted on a field scale, although several factories have had no particular difficulty with it. Other varieties such as Uba, D 1135 and at times H 109, had also given trouble in clarification. It was soon realized that some modification in clarification procedure would have to be practiced to meet the difficulty and allow the factories to operate at normal capacity.

Of the many modifications in clarification procedure that have been tried, the addition of ammos-phos A has given the best results with many moderately refractory juices, particularly those with a low P_2O_5 content. With the more difficult juices, sulfitation has proven to be a very satisfactory solution of the problem.

POJ 2878 accounted for 8.3 per cent of the 1935 tonnage of cane harvested. In 1934 it was 3.2 per cent. At the close of the 1935 crop, seven of the factories that have ground this cane had installed equipment for mixed juice sulfitation, largely as an insurance against clarification difficulties. Two others were preparing to install similar equipment for 1936. The few remaining factories having fair quantities of POJ 2878 have not been seriously affected.

The average crystal color of raw sugar from all factories was more satisfactory in 1935 than in 1934 and also better than in any previous year. The filtrability of the Crockett receipts for 1935 was 3 points better than in 1934 and practically equal to the 1933 and the 1932 averages. The tendency toward better filtration rates is especially gratifying as it is against the expected trend due to the recent gradual reductions in sugar pol.

The subject of clarification is still a major project, with our efforts now directed principally toward modifications which will aid in securing larger elimination of impurities than is obtained by the usual procedure.

The milling quality of POJ 2878 would appear to be in line with that summarized in the report of 1933. The data were largely from Waimanalo Sugar Company's factory as this plantation began spreading POJ 2878 soon after it became available. Extracts from this report are given in the following paragraphs:

Milling: POJ 2878 cane is classed as long-jointed, medium-heavy stalk, self-stripping, with comparatively hard rind. It appears to mill well, that is, feeds into the mills without difficulty under conditions of close settings and heavy pressures. Waimanalo reports that the extraction is slightly higher with this cane than with H 109.

Bagasse Burning Quality: The interior portions of the joints are more pithy than in other canes and the steam generating quality of the bagasse seems to be poorer due to its lightness and fineness. This necessitates a more careful distribution of air through the furnace tuyeres and grates, and close supervision for keeping the grates sufficiently well covered to prevent air holes, but not too thick for rapid combustion.

The mechanical structure of the bagasse from various varieties of cane has appeared to have more influence on steaming quality than moderate changes in fiber content of the cane.

Waimanalo had considerable difficulty through steam and fuel shortage last year when burning any considerable quantity of POJ 2878. The fiber this year was also low at times. In addition to more careful work in the fireroom, they have had to resort to vapor heating in the boiling house to reduce steam consumption.

The thermal value of dry bagasse from POJ 2878 at Waimanalo has been found to be on a par with other varieties at 8330 B.t.u. A number of tests, also made at the Station in 1928, of bagasse classed as good burning and poor burning revealed a minimum of 8037 B.t.u. and a maximum of 8363. A complete survey of all the major varieties in 1912 gave 8089 as the minimum and 8344 maximum.

From present indications the per cent fiber in POJ 2878 appears to be practically the same as in other canes when the juices are of good purity, but with low purities the fiber is low. If purity is judged as a sign of cane maturity, it can perhaps be expected that with mature cane the fiber content will be normal. The tabulated results from the Waimanalo reports indicate a clear relationship between purity and fiber.

Boiling: Present information does not indicate that POJ 2878 juices (after passing clarification) act differently in boiling-house practices than other juices. There is no direct evidence that the quality of commercial sugar is affected nor the purity of final molasses.

Waimanalo Data: Certain laboratory data from the 14 Weekly Mill Reports are tabulated below in which 63 per cent to 100 per cent of the cane ground was POJ 2878. The weeks are arranged in the order of descending purity of first expressed juice, which indicates a close relationship between purity and fiber content and also, as would be expected, the pol in cane.

Crop Week Nos.	First Expressed Juice Purity	Per Cent Fiber	Per Cent Cane Pol
26	84.9	13.41	13.44
27	84.1	13.38	14.01
32	82.9	13.05	12.69
39	82.3	12.13	14.89
41	82.2	13.64	11.77
28	81.7	13.20	14.15
34	81.3	12.23	13.23
31	81.2	13.09	12.17
38	81.2	12.09	13.92
33	81.1	12.98	11.71
40	79.0	12.11	11.34
36	78.7	11.65	13.44
37	78.0	11.90	12.82
35	76.7	11.45	13.15
Average 1st 7	82.77	13.01	13.45
Average 2nd 7	79.44	12.18	12.65

Since writing the 1933 report, POJ 2878 cane has become the principal variety at Waimanalo owing to its superior yield on that plantation in sugar per acre month. The following figures for four crops show two crops of POJ 2878 and two of H 109 when grinding an average of about 80 per cent of these varieties. The figures are taken from Synopsis data.

Crops Avg'd	Per Cent POJ 2878	Per Cent H 109	Per Cent Fiber	Per Cent Pol	Brix 1st Juice	Purity 1st Juice	Cane Ratio
1934-1935	82	None	12.08	11.12	17.05	79.7	10.39
1930-1931	None	79	13.45	11.43	17.32	82.6	9.94

It appears that there is a marked tendency toward lower cane fiber and juice purity and a probable tendency toward lower cane pol and juice density with POJ 2878 than with H 109, at least under Waimanalo conditions. This is perhaps to be expected since the period of growth for POJ 2878 is several months shorter.

Utilization of Molasses

THE USE OF CANE BY-PRODUCTS IN FATTENING BEEF CATTLE

By A. R. Lamb

There are some forty-one cattle ranches in the Territory of Hawaii which carry over 100,000 cattle, of which well over 90 per cent are beef cattle. In addition to these larger ranches there is about an equal number of small ranches. The total number of beef cattle in the Territory was estimated in 1928 as over 157,000. This statistical information, as well as some similar information given below, is the result of a careful survey by Prof. L. A. Henke of the University of Hawaii, the results of which were published in 1929.

According to his survey, the total area of these forty-one ranches is 1,115,200 acres. This is 32 per cent of the total area of the Territory and six times as great as the area planted to sugar cane. Of course, a great deal of this is waste land, with sparse vegetation, but most of it takes its turn, according to season and rainfall, in supporting animals which graze upon it.

A few of the ranches have improved the land appreciably by sowing grasses of better quality which are adapted to the various areas. A few other ranches are fortunate enough by reason of well distributed and sufficient rainfall to have areas which grow plenty of nutritious forage. These few ranges grow animals to maturity efficiently enough so that they fill out well and put on some fat, especially if finished on the best pastures, fenced in and supplied with water.

The Local Market For Beef

Such cattle make fairly good beef, although not as good as that which receives its final fattening on good legume pasture or "concentrate" feeds such as corn, oil meal, etc. This range-fattened beef is marketed locally and in Honolulu. In Honolulu it is apparently marketed mostly at a much cheaper price than well-finished (well-fattened) beef from the Mainland. This Island beef seems to have inherent quality due to good type in the animal on the hoof, but it is tough and somewhat lacking in flavor because it is not "finished" by means of a final fattening period. Such beef has been selling in a good Chinese market at 9 to 10 cents less per pound than the same cuts of mainland beef at Piggly Wiggly Stores.

A large section of the customers on all these Islands buys the cheaper grades of meat and prefers such beef because it is not fat. All of the better class of the trade, however, prefer well-fattened beef, even though some of the outside layer of fat is wasted, because of the effect of the fattening on texture and flavor. It is said that some of the range beef is sold to the Navy, but it does not generally come within the government specifications as to quality and finish, and the Army now brings more than 95 per cent of its beef from the Mainland.

Some idea of the size of the Island market for good beef may be obtained from figures published by the Honolulu Advertiser, presumably from information furnished by the U. S. Customs Service. The amount of fresh chilled or frozen beef

and veal imported in 1932-33 was 3,242,000 pounds, wholesale value, $382,000; and for 1933-34, 3,835,000 pounds, valued at $400,000. Of this amount, about 1,200,000 pounds were imported for the Army.

This is only about 18-20 per cent of the total amount of beef consumed here, since the total beef killed in the Territory in 1934 is estimated at 33,000 animals, yielding 16,000,000 pounds of dressed beef. (Honolulu Chamber of Commerce.) In this connection it must be remembered that the greater part of the beef on any market is always inferior in quality and finish, as in other commodities. A certain fraction of the trade, however, greater or less under varying economic conditions, demands good or choice beef. In this Territory this fraction is probably rather high because of the large consumption of beef by the Army, whose specifications are fairly high and quite rigid. Those ranchers who are so situated that they can "finish" all or part of their cattle mainly on local feeds supplemented with molasses and bagasse should develop such a practice and supply the good beef for the Honolulu market. The others will supply their local markets and the Honolulu market with ordinary range-fed beef, for which there will always be a large demand.

The chief reasons which seem to favor the development suggested are:

(1) The Territory as a whole profits by decreasing imports and increasing local production.

(2) By-products of the sugar industry, as molasses and bagasse, are utilized and their fertilizer value retained on the land. Under average cattle feeding conditions on the mainland, molasses fed at 15-20 per cent of the ration is worth as much pound for pound as corn or barley. If corn were 70 cents per bushel, molasses would then be worth $20.00 per ton.

(3) Cattle from Island ranges are marketed at from two to five years of age, the average apparently being at about three years. Cattle may be finished in dry-lot and marketed at 2 to 2½ years or even less, with greater profits, other things being equal, from the quicker turn-over. This would allow the range to produce more animals on the same area.

(4) Many of the Island ranches have improved their breeding herds with pure-bred beef bulls to the point where steers of excellent beef type are being produced. It is a distinct loss to market such animals without a better realization of their hereditary possibilities in good or choice beef production.

(5) It seems possible, with an abundance of cheap feed, that Island beef could also be shipped to the Mainland, after the industry develops and after the local market is supplied.

Energy in Molasses

The practicability of the development of this industry lies partly in the great amount of cheap energy which exists in the sugars left in waste molasses. These sugars are easily digested and utilized by the animal, and surplus salts and other materials not needed by the animal are excreted. Molasses can be fed in amounts as high as 30-40 per cent of the ration without any ill effect from the large amount of sugars and salts it contains. Its efficiency is a little less at these higher levels than at the 15-20 per cent levels.

Molasses contains plenty of energy in the form of carbohydrate, but contains almost no protein, a substance which is essential as building material for growth, and which is necessary in lesser amounts throughout the mature life of the animal. Molasses must therefore be supplemented with a high protein feed. Growing leafy forages, such as grasses, contain some protein of optimum quality, i.e., containing all the amino-acids; and range-fed animals grow satisfactorily on such feed, provided only that there is enough of it, and the water supply is sufficient. It is possible, indeed, to bring beef animals to a mature, fattened, well-finished condition on grass alone, but there are only a few areas in the world where soil, rainfall and other climatic conditions make pastures good enough, luxuriant enough in growth, and at the same time cheap enough to allow this result. It is not enough, therefore, for the ranges of Hawaii to improve the pastures by sowing better quality grasses. Such improvement of the ranges is much to be desired in order to nourish the breeding herd properly and allow the young stock to grow well and not too slowly.

The production of good beef, however, demands a finishing period during which the feed is properly balanced, abundant and palatable, no long walks are required to get it, and quiet, shade, and shelter, if necessary, promote the consumption of plenty of feed and the laying on of fat and mellowing of the tissues. Under these conditions cattle are content, become more tame, gain weight rapidly (2½ to 3 pounds per day), and the skin and coat become mellow and glossy, things which delight the hand and eye of the experienced cattleman because they mean that the desired effects are going on under the skin. Range animals so fed not only gain rapidly during a 3- to 4-month period, but are worth considerably more per pound on the market.

Digestibility of Bagasse

In order to make quite clear how by-products of the sugar industry fit into the picture, it should be stated that ruminants (as cattle and sheep) in which the first stomach or paunch is very large, obtain considerable energy from the bacterial fermentation of cellulose, pentosans and other plant materials which are not digestible by the digestive enzymes of the body. Organic acids and gases are produced by this fermentation, the former of which are oxidized in the body to yield energy. This fermentation is a normal process by which the fibrous tissues of plants are softened and cell walls broken down, thus allowing the digestive juices to get at the nutrients within the cells. Such materials as straw, corn stalks and cane bagasse, which yield some energy in the digestive tract of horses and similar animals, are more completely fermented in the paunch (rumen) of cattle and sheep. The exact amount of energy yielded in this process can not be known without careful calorimetric digestibility tests, but it is quite considerable, even though much of it is changed into useless gases. Thus bagasse is not only an excellent carrier for the molasses it will absorb, but it also contributes food value to the ration.

As stated above, both molasses and bagasse supply energy but almost no protein. A mature beef animal does not need as much protein as a growing calf, but must have some. The best protein supplement available in this Territory is soybean oil meal, which is imported at a price which is quite reasonable. It happens to be true that the proteins of the soybean are the best of all seed proteins known. Therefore a

smaller amount of this supplement is necessary than of other less efficient protein carriers, such as linseed oil meal. Other protein supplements are possible, such as cottonseed meal, sunflower seed meal, or even fish meal. The last has not been used much for cattle feeding, but its animal protein is most efficient of all in feeding.

The most logical plan for supplying the protein supplement is the cooperative development of the soybean industry in the Islands. Soybeans are used considerably and wisely for human food by Oriental peoples. The oil pressed from the seeds is readily marketable at 10 cents per pound, the same price as linseed oil. The residue after the oil is removed from soybeans is the very excellent high protein feed which we have been discussing. There are other protein crops which can be developed in various localities, such as pigeon peas, which are now being grown on some ranches. If such legume pastures grow luxuriantly on any ranch, the cattle may there secure their protein by grazing over a not too large paddock, with the bagasse and molasses fed in a trough or bunk. Otherwise, it is best to have the protein supplement mixed with the bagasse and molasses.

Feeding Experiments

Feeding experiments are now being carried on by several plantations and ranches in the Territory. A number of different rations are being compared for their relative efficiency in producing gains in the dry-lot feeding of range cattle. The University of Hawaii has carried on experiments with fattening cattle and dairy cattle, the rations including molasses and sometimes bagasse or pineapple bran. Further experiments are necessary in order to determine approximately the most efficient proportions of the feeds available. In localities where other feeds are available, the place in the scheme for their use should be determined.

The most logical "standard" by-product ration is molasses, bagasse and soybean oil meal, supplemented, if possible, with some grass or with cane tops. The latter are quite valuable as a supplementary feed, since, like all green leaves, they supply mineral matter, vitamins and high quality protein. The Honokaa practice of feeding work animals on this type of ration has demonstrated its feasibility. It has not shown us, however, what the most efficient proportion of the various ingredients may be.* It is also true that the proportion of protein feed in this standard ration should be varied somewhat with the type, age, etc., of the animals being fed.

Probably the most satisfactory and economical method of obtaining this experimental information is by the cooperation of interested ranchers in different localities. There is plenty of market for beef from all who are able to develop this type of feeding. The various cooperators could be advised and their experiments correlated from a central point, as the Experiment Station, with the experiments so planned

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*A feeding experiment at the Station, using rabbits as a type of animal with a digestive system similar to that of the horse, has been under way for 9 months. The experimental ration contains 55 per cent ground bagasse, with molasses, soybean oil meal and cane tops. On this ration the animals do their daily two hours in the mechanical exerciser as satisfactorily as do the controls on a ration of alfalfa, barley and molasses.

that the ranches carrying on the tests will learn from them the most efficient method of getting the desired results under their own conditions and with their own local feeds. Each experiment will also contribute to the general knowledge of cattle feeding in the Islands and all will benefit therefrom. Such experiments with relatively few cattle (several groups of about 20 animals each) should precede any large-scale feeding operations.

During the experimental stage finished steers or carcasses should be sent to the Honolulu market in order to develop a knowledge of and demand for such beef. If the chain store markets and other good markets have demonstrated to them that Island beef can be produced exactly as good and as uniform in quality as imported carcasses, there is no reason why local producers should not have this market. There is also no doubt as to the ability of Island cattlemen to produce this quality of beef from their present herds.

The Third International Congress of Soil Science

By Francis E. Hance

Delegates from sixty countries assembled at Oxford, England, on Monday, July 29, 1935. Stewards met the trains, conveying the guests first to reserved accommodations in the various residential Halls of the University and later to the reception room and headquarters of the Congress in the Hall of Wadham College. Delegates were registered, supplied with publications and literature bearing upon the Sessions of the Congress, given membership identification lapel buttons and assigned in groups to student guides, the latter to function for the period of the Congress.

The meetings opened on Tuesday, July 30, at Rhodes House, with an Address of Welcome by the Vice-Chancellor of Oxford University, followed by the Presidential Address of Sir E. J. Russell and reports by other officials of the Congress.

The work of the Congress was started on Wednesday, July 31. Deliberations of the Congress were held in plenary sessions at Rhodes House in the mornings, followed in the afternoons by separate or joint sessions of six commissions and three sub-commissions.

The work of the Society by Commissions was distributed by topics among the following subjects:

1. Soil physics
2. Soil chemistry
3. Soil microbiology
4. Soil fertility
5. Soil genesis, morphology and cartography
6. Application of soil science to land amelioration

5a. (Sub-commission) Alkali soils
5b. (Sub-commission) Forest soils
6a. (Sub-commission) Peat soils.

Participation by a single individual in all of the work of the commissions and sub-commissions was, of course, a physical impossibility because six or more commission groups worked simultaneously.

Early on the morning of each session day, a detailed program for that day was posted at headquarters. Delegates were privileged, therefore, to arrange their attendance at sessions best suited to their needs and interest.

Several outstanding figures in the world of soil science attended the Congress. Personal discussions were made possible at informal gatherings of members during the late afternoon teas after commission sessions had closed.

Deliberations of the Congress were concluded on August 7, 1935. The meetings at Oxford were followed by a post-congress tour of Great Britain in which studies were made of the soils of North Shropshire, Wales, The Highlands, North Eastern Region, Central Valley and Southern Uplands of Scotland; Yorkshire and East Anglia. Following a luncheon at the University Farm, the excursion terminated at Cambridge on August 23, 1935.

Many papers were presented to the Congress on a great variety of subjects. Of these, a large number was of particular interest and value to plantation men. Rather than present an abstract of the contributions, it is the author's belief that perhaps a more concise digest of the meetings attended may be found in the notes recorded at the end of each session day. This plan of presentation allows introduction of the highlights of discussion which took place among small groups at the many informal occasions where impromptu meetings were held. The "notes," supplemented by quotations, are rearranged by topics.

The Soil Survey:

The importance of soil-water relationships was emphasized for an initial survey of agricultural land. Attention was given to presence of salt, alkali or other soluble mineral deposits and the physical or chemical effects of these materials upon the colloidal structure of the soil under natural or artificial irrigation. The profile examination and chemical analysis of the soil contributed not only to the water-relationship study but furnished a means of soil classification and definition according to types and in addition gave valuable information as to the suitability of the land for the crops designed to be grown upon it.

Field experiment was looked upon as an essential part of an agricultural survey. It was proposed that field experiment might serve as a complement to chemical analysis. A few urged that field experiment should replace chemical analysis. One prominent member stated that in his experience field experiment had been found severely limited in its serviceable applications. He proposed that the profile and chemical survey be employed as the basis for laying out and placing the field experiment and interpreting the resultant data.

Mitscherlich tests, aspergillus studies and other methods of soil analysis received favorable mention in this connection. In an informal discussion it was proposed that after the determination of soil profile characteristics, soil-water relationships and total chemical analyses of new land, the agriculturist could employ field experiments, Mitscherlich tests and reliable rapid chemical soil and crop analyses in correlation, with crop yields, in deciding upon the program of fertilization for any given soil type, district and crop. It was agreed that an understanding and full cooperation between the water scientist, the agriculturist and the chemist were essential to the success of intensive agricultural pursuit.

Soil Reaction (pH):

The agricultural significance of soil reaction was shown to be important and to have a direct relation to physical and chemical soil characteristics. pH considerations, base replacement, phosphate fixation, movement of soil nutrients and textural differences in soil appear, to a great extent, to be interdependent.

The rather general and present trend toward the extensive employment of acid-forming nitrogen fertilizers, particularly on normally acid soils, were shown by replicated field experiment at Rothamsted to have brought about acute infertility. The oxidation in the soil of the ammoniacal fertilizers to acids appears to result in the replacement of soil bases such as potassium, calcium, magnesium, etc., by the hydrogen of these acids so that the bases are present in solution and are readily lost

by leaching. When reactions such as these occur in the field and have progressed for a number of years, the fact may be determined by a study of the soil reaction.

Under the caption of "Calcium" it will be shown that a restoration of fertility may be accomplished by rigidly controlled liming of naturally acid fields that have been rendered infertile by ammoniacal dressings. A reclamation of this character is always accompanied by a partial and, on occasion, by an almost complete neutralization of the soil acidity induced by the ammoniacal fertilizer. Control in this case employs pH determinations. Other important physical and chemical considerations are involved as a result of the lime treatment. These will be discussed later. To offset the accumulative development of acidity in soils as a result of employing acid-forming nitrogenous fertilizers, the English fertilizer manufacturers have produced a number of new ammoniacal fertilizer mixtures which contain either neutralizing or non-neutralizing compounds of calcium. These new fertilizers are designed for use on fields which have received a primary corrective lime treatment. It has been claimed that when used as a substitute for sulfate of ammonia, one of these new products, for instance, "nitrate of chalk," will *not* contribute to an increase in soil acidity, the loss of nutrient bases nor to a reversion to infertility. It should be emphasized that the cumulative acid effect of the ammoniacal fertilizers in the field became acute at Rothamsted after a continuous and yearly repetition of the fertilizer applications for a period greater than fifty years; also that the soils receiving this treatment were originally acid in reaction and became considerably more acid in the interim. The severity of the phenomenon in localities other than England and Continental Europe was questioned by a few Congress members. The fact remains, however, that no data were submitted by those dissenting, as far as the author is aware, which had been obtained from a similar, continuous fertilizer plot study having a duration of fifty years or more.

The crop (hay) in the Rothamsted experiment, fertilized by sulfate of ammonia, was admittedly one sensitive to increases in soil acidity. Some crops, particularly sugar cane, exhibit a high degree of tolerance to acid soils. It may be found, therefore, that the acid tolerance of the crop, in addition to the pH and the chemical composition of the soil, govern to some extent the period involved in the appearance of soil infertility when induced by the uncompensated use of acid-forming nitrogenous fertilizers.

Relative to corrective amendments used to overcome soil acidity, one investigator reported satisfactory results with carbonate of lime when mono-ammonium phosphate had been used to fertilize a soil under 5.5 pH. Another found a mixture of superphosphate and sulfate of ammonia equally effective for cereal crops. In both cases increases in soil acidity had apparently been checked. Nitrate of Chalk, mentioned previously, is manufactured on a large scale in Great Britain. It consists of a mixture of ammonium nitrate and calcium carbonate. This product is marketed in the form of small granules and is surprisingly stable under conditions of ordinary exposure. It has been reported, however, that Nitrate of Chalk gives off a small amount of ammonia on long storage. A similar product manufactured in Norway consists of equal parts of calcium and ammonium nitrates. This mixture also is furnished in globular pellets and is said to be quite satisfactory to handle even in damp weather. pH determinations by B. A. Keen of the soils of the "classical"

experimental plots at Rothamsted and Woburn gave results of interest. A study was made of the changes produced in the soil by the long and continuous use of various fertilizers. In regard to the liming of soils it was shown that changes in the pH values which occurred in the field were less than those determined by lime requirement tests in the laboratory because of subsoil acidity. It was shown that changes in reaction on the surface layers of soil due to liming penetrated to and affected somewhat the lower horizons to a depth of three feet. Also that these subsoil changes in pH were contributory to differences in soil texture which were not apparently simple functions of pH. Quoting from the report:

> The top soil, although the most acid, showed no flocculation, probably owing to the protective action of the humus colloids; the 4½- to 9-inch depths showed distinct flocculation but the suspension remained turbid; the lower depths flocculated completely and immediately, possibly owing to the accumulation of calcium and aluminum ions leached down from the very acid surface layer. These textural differences will affect air and water movement within the soil; they are important, indirect factors in the relationship between soil reaction and crop growth.

Calcium:

Base exchange soil phenomena have been studied by many investigators and have been discussed in the literature for years. The useful and practical applications of base exchange principles in soils studies have been increasing rapidly with the development of this branch of soil science. The mechanism of exchange is a simple one in principle but in the soil of the field, exchange reactions are governed by several factors, among which one of the most important is the base calcium.

Calcium is an essential plant nutrient. Some of its compounds have wide application in correcting excessive soil acidity. Ample exchangeable calcium in the soil exercises a direct control upon the establishment of potash and other bases in the nutrient reserve; it acts as a buffer in retarding the development of soil acidity; it contributes to a desirable condition of soil tilth and granulation and it establishes a "seat of exchange" where applied potash fertilizer may be held secure from wasteful leaching and yet function normally as a freely available source of the nutrient. One very prominent member, an outstanding authority on base exchange, decried the common practice of wholesale liming of fields without any degree of control. He suggested that calcium be looked upon as a plant nutrient as well as a soil amendment and that it should be employed much the same as other nutrients, except where its compounds were used to neutralize soil acidity and to establish a "seat of favorable exchange." Discussion of the subject brought out observations upon the beneficial effects of lime when applied to soils as a corrective after years of leaching by heavy rainfall. It was stated that the exchangeable bases in clay soils may be regarded as bound to distinctive alumina-silicate clay acids. During leaching of this soil by rainfall in humid climates exchangeable bases are carried away and replaced by acid soil hydrogen. Lime applications assist in the amelioration of soil colloids and insure enrichment of the clay-humus soil fraction with subsequently added potash. It was shown that neutral potash fertilizers (muriate of potash is an example), when applied to acid soils deficient in calcium, do not "form a supply" in the soil and will not do so in some soils until the excessive acidity is reduced by adequate treatment with lime. This may be considered a questionable claim, perhaps, for it could be assumed that since the greater amount of acid hydrogen in the

soil is essentially exchangeable hydrogen, it should be "replaced" by applications of other bases, potash compounds, for instance, since these are used in ordinary fertilization. Such is not the case, however. An illustration presented by D. J. Hissink at the Congress makes this point quite clear. He stated:

> Manuring with potassium is almost always done with neutral potassium salts soluble in water, chiefly muriate and sulfate of potash. Experiments have shown that in this way no supply of potassium is formed in the soil in strongly acid soils. It is not until the soil reaction of these strongly acid soils has been made less acid by means of liming that a stock of potassium is formed in the soil with potassium fertilization. This phenomenon may be explained in the following manner. In slightly acid to slightly alkaline humus-clay soils, the potassium of the potassium fertilizer finds enough lime in the soil for exchange. In strongly acid soils, however, the potassium of the potassium fertilizer has to exchange itself against the (acid) hydrogen of the soil and the soil hydrogen can only be replaced to a slight extent by treatment with solutions of neutral salts. The following reaction is what takes place:

$$\underset{\text{(Soil acid) plus (Muriate of Potash)}}{\text{Soil H} + \text{KCl}} \leftrightarrow \underset{\text{(Soil potash) plus (hydrochloric acid)}}{\text{Soil K} + \text{HCl}}$$

> Theoretically speaking, it is easy to understand that, owing to the strength of the hydrochloric acid formed, this equilibrium shifts only slightly to the right. If, however, the test is carried out in such a way that a solution of muriate of potash is poured over the soil, so that the hydrochloric acid formed is leached out, there is no apparent reason why this process should not continue. Yet this is not the case. Experiments were made by Ramann in which he leached out the soil with a few hundred liters of muriate of potash solution, without succeeding in replacing more than a very slight amount of (acid) hydrogen with potassium. . . . There is only one (practical) way to bring about an immediate and complete replacement of the acid soil hydrogen, and that is the treatment of the soil with basic compounds or hydroxides (calcium hydroxide or mill lime, raw rock phosphate, coral rock or coral sand, etc.). In this case the soil hydrogen combines with the hydroxide (the coral or the phosphate) to form harmless water, e.g.

$$\underset{\text{(Acid hydrogen) plus (lime)}}{\text{Soil H}_2 + \text{Ca(OH)}_2} \leftrightarrow \underset{\text{(Replaceable soil calcium) plus (water)}}{\text{Soil Ca} + 2\text{H}_2\text{O}}$$

Dr. Hissink concluded his remarks in this manner:

> When the soil, this living organism, which is able to render plant growth possible, has lost the adsorbing soil complex, it becomes a completely sterile thing, a dead body, which is of no further value to plant life. It is, therefore, one of the most important tasks of agriculture to prevent the disintegration and ultimately the complete destruction of the adsorbing soil complex. Although perhaps other measures, such as, for instance, rational plowing, may be appropriate, I will only point out in this address that an ample application of lime to the adsorbing soil complex is the measure par excellence, for the reason that the adsorbed calcium does most to check the destructive activity of water (water containing carbon dioxide or water flowed upon treatments of acid-forming fertilizer salts). In other words, adsorbed calcium gives the greatest stability to the adsorbing soil complex. And so I may best conclude this address by repeating in a slightly altered form Tacke's pronouncement with which I began a treatise on the soil lime question twenty years ago. *(The lime question is by far the most difficult and at the same time by far the most important problem of the theory of manuring.)*

Summarized, it may be restated that in the regions of heavy rainfall in humid climates, soil acidity tends to become more acute by the leaching downward of exchangeable bases, and the substitution in their place of acid hydrogen. Without the stabilizing influence in the soil of the exchangeable bases, chiefly calcium, losses occur, by leaching, of applied potash fertilizer and other nutrient constituents. To insure adequate adsorption of potash fertilizer by a crop in such a soil it becomes

necessary to add to that soil sufficient lime to partially neutralize the increased acidity and to establish a seat of exchange where the potash and other bases may be held against leaching and in a form usable by the crop. The long continued application of acid-forming nitrogenous fertilizers on any soil, other than coral lands and alkali districts, may be expected in time to result (1) in the development of increased soil acidity, (2) in failure to hold potash against leaching, and (3) in loss of exchangeable bases. The remedy appears to consist in the use of lime in one or more of its several combinations simultaneously with, or in addition to, the acid-forming fertilizers. Lime applications to the soil have also been found beneficial when previous action of the elements and time have increased soil acidity and have resulted in the removal from the soil of the greater part of its exchangeable basic fraction. Unquestionable support of these conclusions has been found in experimental field studies in England and in Holland.

On the naturally acid soil plots at Rothamsted which had become infertile and more acid as a result of fifty years of continuous fertilization with sulfate of ammonia, in a complete fertilizer mixture, exchangeable calcium had disappeared almost entirely from the soil and the loss of potash by leaching had become severe. Reclamation was made by application of lime. Chemical studies conducted in this research gave added weight to the premise that the alkaline lime treatment had replaced the excess of acid soil-hydrogen, thus allowing the base, calcium, to become a useful part of the replaceable soil complex. Further evidence was found to substantiate the belief that subsequently applied potash then found sufficient calcium for exchange and the reconstructed soil complex was accordingly supplied with the required plant potash. It is assumed, of course, that other basic nutrients are similarly involved—all to the apparent advantage of soil and crop.

An interesting study was concluded recently at Rothamsted in which 55 years of continuously cultivated wheat and barley on plots at Woburn gave additional information of value relevant to acid nitrogenous fertilization, lime treatment of soil and soil organic matter. During fifty years of this period without applications of farmyard manure, one-third of the soil organic fraction was lost. It required seven tons of farmyard manure per year under the same crop, on neighboring plots, to maintain the soil organic fraction at a fixed concentration. Superphosphate did not influence soil reaction nor affect the base status of the soil in others of these plots during fifty annual applications. A number of plots which had received sulfate of ammonia for fifty years and had become acutely infertile were subsequently divided for attempted reclamation by lime. Study of these plots by E. M. Crowther yielded data which showed that the rate of loss of lime became less as the soil developed increased acidity. This finding illustrates the correlation between diminishing calcium reserves and increased soil acidity. In a study of the comparative effect of nitrate of soda and sulfate of ammonia on the lime reserves of these soils, the following conclusion was reached. If lime were to be used to maintain the chemical composition of soil and crop at concentrations comparable to those of soil and crop under nitrate of soda fertilization, the amount of lime which would be required would be equivalent to the combined nitric and sulfuric acids produced in the oxidation of the sulfate of ammonia used. Unfortunately this concise statement is rendered somewhat obscure by the additional finding that nitrate of soda has

a much more beneficial effect on plants growing in very acid soils than can be accounted for simply by the reduction in loss of calcium by leaching.

An American investigator, M. F. Morgan, presented data compiled from a lysimeter test conducted on soils kept free of vegetation. A study had been made of the comparative effects upon uncropped soil of sulfate of ammonia, urea and nitrate of soda. The conclusions reported agreed in many respects with the findings of European investigators. In the study with sulfate of ammonia it was reported that:

1. In spite of applications of potash to the soil, exchangeable potash was depleted.
2. A reduced degree of base saturation occurred.
3. Aluminum and manganese salts appeared in drainage water.
4. The loss of calcium in the leachate was large.

Where urea was used the results obtained were similar in effect to those observed with sulfate of ammonia. The effect upon soil bases, however, was less severe.

With nitrate of soda, it was reported that:

1. Exchangeable sodium increased slightly.
2. A minimum loss of other bases occurred.
3. Applied potash was held in the exchangeable form.
4. Less calcium was leached from the soil than in other cases.
5. There was no marked change in total base exchange capacity.

The advantageous role of calcium in soil-base exchange reactions has been shown to be an important one. The organic fraction of the soil also appears to have an important bearing upon base exchange matters. One delegate to the Congress, Prof. Sante Mattson, an outstanding authority on soil chemistry, presented a paper upon pH and base saturation of the podzol profile. He stated:

> Some of the soil bases exist in combination with organic acids of the more simple and soluble type. But, while considerable quantities of bases may be stored up in the humus, these bases or metal cations are of little direct benefit, because their release involves a still further lowering of the pH. If, however, the conditions which favor the production of humic and other organic acids should be succeeded by conditions which favor the complete decomposition of the organic matter into water and carbon dioxide, we can easily foresee some of the immediate results. After the destruction of some of the humic acids the residue would attain a higher degree of base saturation and the pH would increase. The acid hydrolysis would then cease, less bases would be lost by leaching, and the soil complex would become positively saturated with bases throughout the profile.

The practice of incorporating filter cake, molasses and cane trash with the soil is not an uncommon one in Hawaii. It was shown in Prof. Sante Mattson's contribution that the return of vegetable residues to the soil occasions an increase in the supply of bases and tends to counteract the development of soil acidity.

"Slowly" Available Soil Phosphate:

We have been accustomed to differentiating soil phosphate as "difficultly soluble" and "readily soluble (or available)." That there must exist in the soil an intermediate supply of phosphate between these two extremes of solubility, there can be but little doubt. It was of interest, therefore, to learn that E. Truog and L. A. Dean, having determined the occurrence of this intermediate supply, had submitted to the Congress the findings of their research. They described a unique quantitative method of ascertaining simultaneously the concentration in the soil of "readily available" and "slowly available" phosphate. Their method may be found in the Transactions of the Congress. A brief description follows: A high ratio of weakly acid solvent to soil is employed. Hence, while tricalcium phosphate is readily dissolved, allowance is made for measurement of rate of hydrolysis of phosphate from basic iron phosphate. The solvent does not dissolve sufficient iron from the soil to interfere with colorimetric readings. The prosphate thus dissolved is considered as readily available. If, however, the amount found is low, they show the advantage of ascertaining whether the phosphate found came largely from a "moderate" supply of tricalcium phosphate or a "good" supply of basic iron phosphate. Basic iron phosphate would be more desirable in such a case, they stated, because of its slower rate of solution during the period of crop growth. To learn the nature of the phosphate supply, the analyses are twice repeated exactly as in the first case with the exception that the soil sample is reduced in amount by one-half and again by one-fourth of the original amount employed. If it is found that a marked falling off in concentration of phosphate occurs in the subsequent analyses, then tricalcium phosphate predominates in the sample. If, on the other hand, the concentrations found do not become markedly less, the results indicate that basic iron phosphate predominates.

A Note on Manganese:

The laboratory of Miss Brenchley at Rothamsted has been the scene of researches of world-wide significance upon the role of the minor elements. J. P. Martin, W. T. McGeorge, L. E. Davis, R. K. Conant, W. W. G. Moir and others have shown in Hawaii that manganese is essential in the metabolism of sugar cane and that it functions specifically in the control of Pahala blight of sugar cane. It was of interest, therefore, to learn in Miss Brenchley's laboratory that a great many other crops also require manganese in minute amounts and for the same apparent reasons that it is required by sugar cane. A new feature of the requirement, however, that the writer believes has escaped our attention, was the finding that the actual amount of manganese present in the soil was not critical but that the proportion of this element present in exchangeable form was the factor which governed its useful function. When naturally present, or when once established in the soil, it appears that replaceable manganese continues to exercise its desirable effect only as long as its concentration is maintained at some, as yet undetermined, but exceedingly low value.

The Estimation of Active Chemical Factors in Plant Nutrition:

Members of the Congress were given opportunity to become acquainted with

Dr. M. F. Morgan's Rapid Chemical Tests for determining the availability in the soil of the major plant nutrients. The Morgan analyses differ from ours in methods of soil extraction, elaboration of detail in analytical procedure and in specialization of determination for the type of information sought.

The Morgan determinations are described as "micro-chemical tests"—ours as "rapid chemical analyses."

Morgan employs a "universal" solvent for all "tests." It is a half normal solution of acetic acid buffered at 4.8 pH with sodium acetate. This single soil-extracting solution is employed for the development of colorimetric or turbidity tests in determining nitrates, nitrites, ammonia, phosphorus, calcium, magnesium, aluminum, manganese, iron and sulfates. A single extraction of a level teaspoonful (5 grams) of soil and 10 ml of universal extracting solution is said to remove from the soil approximately three-fourths of the nitrates, one-half of the ammonia, calcium, potassium, magnesium and manganese, one-tenth of the aluminum and one-twentieth of the phosphorus. Charts are provided for estimating the test results "in pounds of nutrient per acre." Ten drops of the solution extracted from the soil specimen are used in all tests except that for nitrates, where one drop is sufficient. For ammonia, four drops only are required and for aluminum two drops have been found to be ample.

The nitrate test employs the diphenylamine reaction, while nitrites are estimated by means of Lombard's reagent, hydrochloric acid and sodium hydroxide. Ammonia is determined by the well-known Nessler's reagent. Phosphorus is estimated by the ceruleo-molybdate reaction. Potassium is identified as potassium cobaltinitrite, the precipitation being accomplished by employing isopropyl alcohol. Calcium is estimated as oxalate while a color development is used for magnesium, either paranitrobenzene-azo-resorcinol or Titan yellow reagent with subsequent addition of sodium hydroxide. Hematein is used in the aluminum test and the soil extract is made weakly alkaline for the manganese test with benzidine. Sulfates are precipitated with barium chloride, ferric iron is shown by color changes upon the addition of potassium sulpho-cyanate and ferrous iron by potassium ferricyanide.

In the majority of cases but one drop of an appropriate reagent is required to develop a readable test, the final reading being obtained within one or two minutes. An experienced operator of the Morgan "tests" may cover the entire series of estimations on as many as seventy-two soils in one working day—a total of about 864 nutrient determinations per day.

In support of the Hawaiian plantation analysts who are performing not "micro-chemical tests" but duplicated and checked quantitative rapid chemical analyses of soils, plant materials, mill by-products and irrigation waters, the following statement, taken from a record available at the moment, may be made: "During the harvesting season one analyst has collected and composited representative soil samples on two-acre blocks from 2600 acres, air-dried and screened the specimens and has analyzed each (in duplicate), determining potash, calcium, phosphate, phosphate fixation, soil reaction and soil nitrogen."

Summary

This paper is essentially a resumé of notes made by the author while in attendance at the Sessions of the Third International Congress of Soil Science in England. Topics discussed are: Soil Survey, Soil Reaction, Acid-Forming Nitrogenous Fertilizer, the Functions of Calcium in (1) Base Replacement, (2) Correction of Soil Acidity, (3) Amelioration of Soil Colloids, and (4) In the Conservation of Applied Potash; Manganese and Estimations of Active Chemical Factors in Plant Nutrition.

Notes on *Pythium* Root Rot

VIII

ABSORPTION OF ESSENTIAL ELEMENTS BY SEGREGATED ROOTS OF SUGAR CANE

By C. W. Carpenter

The nutrition of the sugar cane plant and its effect on the susceptibility of the roots to *Pythium* root disease was recently discussed by the writer (1). It was mentioned in that article that small shoots of sugar cane, excised from germinated cuttings, had been grown with one or more roots detoured to suitable containers in order to supply specific chemical elements. These experiments, wherein the plants were grown to large size either in soil or in culture solutions, with individual roots supplying elements deficient in the medium in which the remainder of the root system was growing, contributed to our knowledge of the probable effect of localized fertilization in the field.

Hance (3) has devised fertilizer briquettes designed to supply nutritive elements deficient in the soil and to meet problems of fixation of certain nutrients. Such elements applied to the soil in the usual way might be fixed and remain relatively unavailable to the plant. The behavior of the plants in the experiments with individual roots detoured as mentioned above supported the view of Hance that localized fertilization in the cane furrow was feasible, provided the soil moisture was not a limiting factor.

In studies already referred to (1) a series of cane plants was grown in phosphate-deficient soil with one root of each plant detoured into a solution of sodium phosphate. The improved growth of the plants thus supplied with phosphorus in contrast to control plants with no external increment of phosphorus indicated that the one root with its abundantly developed branches supplied this element in sufficient amount to materially benefit the plants. When one root was functioning in this manner there appeared to be a decrease in the severity of the *Pythium* root rot* in the remainder of the root system in the soil.

Similar results were observed with cane plants grown in culture solutions deficient in either phosphorus or potassium, and with individual roots detoured respectively into solutions containing these elements. The growth of such cane plants during a period of six months was comparable to that of control plants in complete nutrient solution, and to plants of similar age in the field. In contrast, plants grown in solutions deficient in either phosphorus or potassium were less vigorous, and the root systems were conspicuously affected with *Pythium* root rot. The "firing" of the leaves and the red mottled midribs characteristic of potassium deficiency of sugar cane as reported by Martin (5) and Hartt (4) were apparent in the plants growing in the solution lacking potassium, but no symptoms of potassium deficiency

* Caused by *Pythium graminicolum* Subr.

were observed in the plants where one root was permitted to develop in distilled water containing potassium.

The above experiments indicated that different roots could supply the plant with specific elements available in their vicinity and that soil solutions corresponding to a complete nutrient solution might not be required at any one point in the soil for the plant to function normally. These observations led to the experiments described in this paper, wherein each of the nine elements, considered essential for normal cane growth, was supplied to individual plants through a separate root. No record of the growth of plants in this manner, which may be referred to as segregated root nutrition, has come to the attention of the writer.

The complete nutrient solution used was modified from the formula described by Martin (5). The table shows the composition of the solution and the parts per million of each element. Solutions of the chemically pure compounds numbered one to nine in distilled water were used for the separate roots. The compound used in each unit solution supplied one of the nine nutrient elements under consideration.

Solution No.	Source of Essential Element	Element	Mol. Conc.	P. P. M.
1	$NaNO_3$ (Sodium nitrate)	N	.009	126
2	$NaH_2PO_4 . H_2O$ (Mono-basic sodium phosphate)	P	.001	31
3	K Cl (Potassium chloride)	K	.004	156
4	$CaCl_2 . 2 H_2O$ (Calcium chloride)	Ca	.006	240
5	$MgSO_4 . 7 H_2O$ (Magnesium sulphate)	Mg	.001	24
6	$FeSO_4 (NH_4)_2 SO_4 . 6 H_2O$ (Ferrous ammonium sulphate)	Fe	...	10
7	$MnSO_4$ (Manganous sulphate)	Mn	...	0.25
8	H_3BO_3 (Boric acid)	B	.00002	0.216
9	$Na_2SiO_3 . 9 H_2O$ (Sodium silicate)	Si	.00001	0.28

Cuttings of the cane variety H 109 were allowed to germinate in wet bagasse. Shoots measuring about 12 to 16 inches from base to leaf tips were severed from the cuttings, rooted in complete nutrient solution and permitted to develop therein. The solutions were renewed once a week. After six weeks, when the plants had become well established in the complete nutrient solution, three plants of uniform size were selected. One was retained as a control plant and grown continuously in complete nutrient solution in the usual manner. All but ten roots of each of the other two plants were excised. Nine of the roots of each plant were detoured respectively into the nine solutions shown in the table, with one reserve root of each plant detoured into distilled water.

The plants were set for anchorage in dry quartz sand in aluminum pots provided

with suitable outlets. The quartz sand was previously washed with hydrochloric acid and then with distilled water. The photographs show the arrangement of the roots, glass tubing and bottles of nutrient solutions. The assembly was enclosed in a suitable box to protect the roots from the light and prevent the growth of algae. The bottles of brown glass were provided with rubber stoppers fitted with two

Fig. 1. Cane plant grown from a small severed shoot with nine roots segregated respectively in solutions of nine essential elements.

glass tubes; one tube was curved with the short arm inserted through the rubber stopper; the other, a straight tube, permitted the use of a smaller glass tube in siphoning and renewing the nutrient solution at weekly intervals. When the bottles and vertical tubes were filled to the proper level, the solution partly filled the curved tubes so that the tips of the selected roots could be immersed in the solution. The roots grew and followed the bore of the tubes into the bottles. A complete solution was maintained in the bottles for two weeks thus allowing the roots to grow through the tubes and become established in the solution in the bottles. Thereafter the appropriate solution containing but one essential element was used in each bottle.

Normal and comparable growth of the three plants prevailed for the first four months. Thereafter the two plants with all roots in the closed bottles fell slightly

behind in comparative vigor of growth; at six months they were noticeably smaller than the control plant. All, however, had developed stalks about one inch in diameter and five feet in length (exclusive of the leaves). The slower growth of

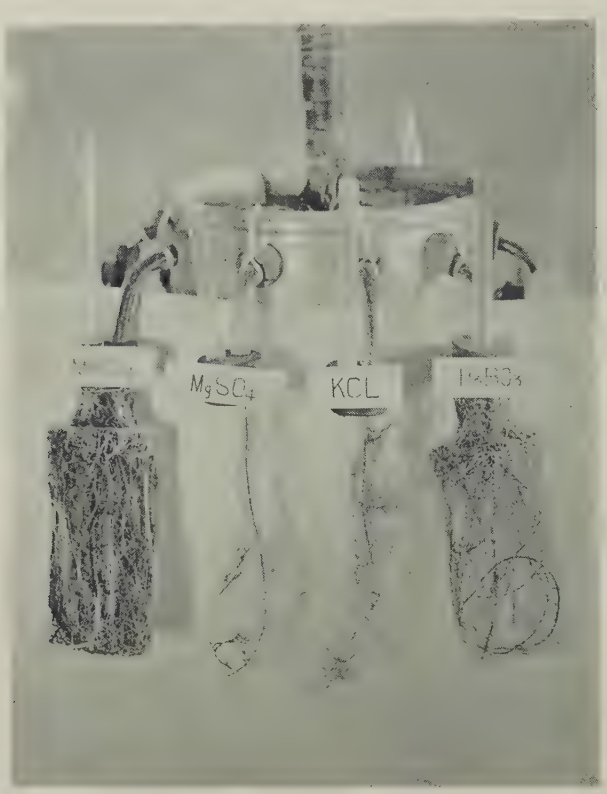

Fig. 2. Root systems developed from individual roots segregated respectively in solutions supplying manganese, magnesium, potassium, and boron.

the plants with segregated roots might be attributed to the restricted root development and the consequent reduced absorption area in the bottles; to the very limited capacity of the nine roots to transmit water and nutrients into the stalk base; and to the lack of aeration of the culture solutions, as compared to the exposed surface of the culture solution in the control jar.

The photographs show the root systems which developed in the several solutions of the essential elements. The dissimilarity of the roots in the various solutions was striking. The experiment has been repeated with similar results. The largest mass of white, vigorous roots, completely filling the contour of the bottle with a thick mat (Fig. 3) developed in the calcium chloride solution in duplicate sets of the two experiments. These root masses were in marked contrast to those which developed in any of the other solutions (Figs. 2, 3 and 4). It is not assumed that these odd experiments are conclusive or that the observations are sufficiently complete for

far-reaching interpretations. Factors other than the presence of the one element, essential to plant growth, in each of the nine solutions, e. g., concentrations and pH values, may have influenced the sizes and types of the root masses. No doubt a

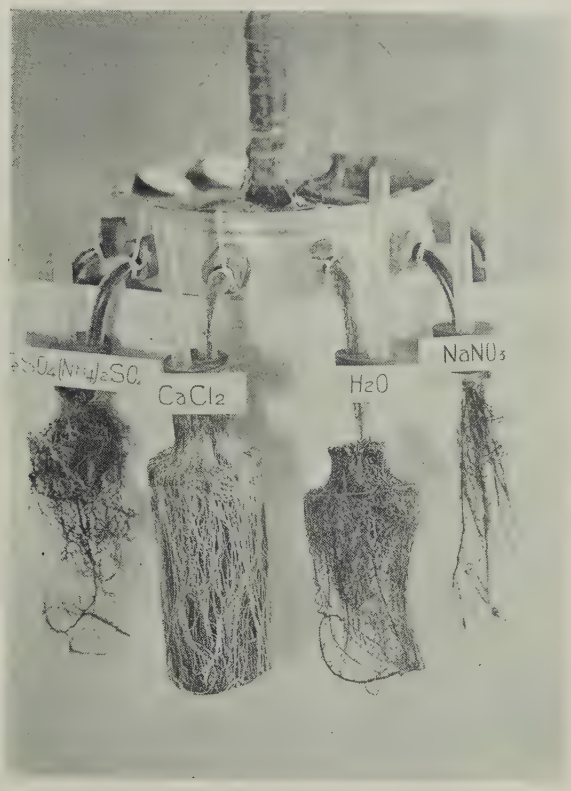

Fig. 3. Root systems in solutions supplying respectively, iron, calcium, and nitrogen. (See Fig. 2.)

portion of the growth of the plants may be attributed to the nutrients stored by the plants during the early stages of the experiments.

It is thought that experiments of this nature may provide useful information regarding the cane plant. Cooke (2) reported increased growth of sugar cane and Sudan grass following large applications of phosphate to certain soils where *Pythium* root rot was a factor in growth depression. The experiments detailed herein led to other tests* which supplemented the observations of Cooke and showed that part of the response accompanying large applications of phosphate was due to the calcium portion of the fertilizer. In pot tests with the Hamakua growth-failure soil, applications of phosphorus and calcium tend to increase the resistance of cane and Sudan grass to *Pythium* root rot.

* Discussed in the Director's Monthly Report of this Station for July and December, 1935.

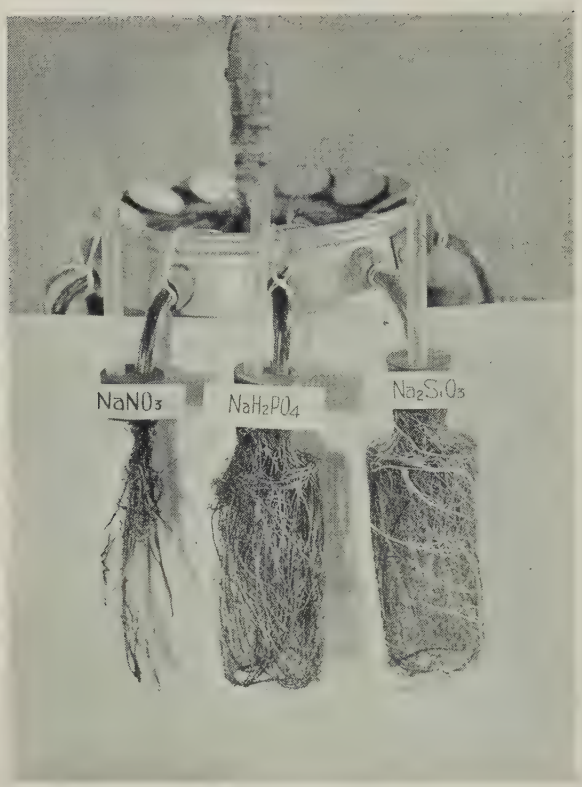

Fig. 4. Root systems in solutions supplying respectively, nitrogen, phosphorus, and silicon. (See Figs. 2 and 3.)

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Cane Growth Studies

THE DOMINATING EFFECT OF CLIMATE

By R. J. Borden

It is extremely doubtful if many of our own agricultural workers have fully recognized the dominating effect that even such small differences in climate as exist throughout the sugar cane districts in Hawaii can have upon the results of their efforts to produce sugar in the field. U. K. Das has repeatedly called attention to various weather relationships that exist, and in 1934 he reported* the results of a pot experiment which prompted us to plan another and more elaborate test of a similar nature. This new test† was designed to note the effects of a difference in the climatic environment upon the growth and production of sugar cane, using different soils, different varieties, and when different amounts of plant food were made available.

The Plan and Conditions

The Climatic Conditions: Since facilities were available for this study at both Makiki and the Manoa Substation, where the elevation is 40 and 550 feet respectively, and since these two locations enjoy differences in their daily and annual amounts of rainfall, wind, temperature and sunlight, the various treatments that are listed hereafter were duplicated at each of these places in order to provide a series of comparisons that would allow us to interpret the effect of some of these climatic influences.

In order to narrow down the sum total effect of all climatic factors, a protected area was chosen at each location where wind would not be likely to be a mechanical-effect factor. To offset any possible deficiency of soil moisture, all treatments were irrigated periodically and sufficiently to keep the plants growing; hence a lack of rainfall was not a growth-effect factor. We are chiefly concerned, therefore, with the factors of temperature and sunlight. Previous records of the sunlight differences show that Manoa receives approximately 40 per cent less sunlight than Makiki, being more generally overcast, especially in the afternoons. A comparison of the average rainfall and temperature for the two locations would show that Manoa has an annual rainfall of over 200 inches as compared with less than 50 inches at Makiki, and that the average minimum and maximum temperatures at Manoa are in the neighborhood of 67° and 79° respectively, as compared with 68° and 85° at Makiki. During the particular 14-month period through which the canes in this study were growing, the following conditions were recorded:

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* "A pot experiment with cane grown in the same soil but under different climatic conditions" by U. K. Das, *The Hawaiian Planters' Record*, Vol. XXXIX, pp. 26-29.

† H.S.P.A. Experiment Station Project A-105, No. 43.

Location	Total Rainfall	No. of days with rainfall exceeding 4″	3″	2″	1″	½″	Mean Min. Temp.	Mean Max. Temp.	Total Day-Degrees
Makiki	46.96	1	0	1	5	13	67.5°	84.6°	6445
Manoa	198.94	5	7	7	34	46	67.4°	80.2°	4488

Soils: Two distinctly different soil types were selected: (1) The Manoa soil is a yellowish-brown silty loam, with a granular structure which makes it porous and well-drained. It is a soil that has been formed, in place, probably from coarse, volcanic ash under conditions of rather heavy rainfall. Thus it is deficient in available basic constituents, especially potash and calcium. It has a very high capacity to fix phosphate. The availability of its phosphoric acid is considered to be rather low, and it has responded to applications of phosphate fertilizers. It has a fair amount of available nitrogen and is quite high in organic matter. In the field it has a pH of about 5.4. It has supported cane growth very feebly, even when well fertilized, and hence it has been considered a "poor" soil for sugar cane. (2) The Makiki soil is a chocolate-brown loam of a much finer structure, which takes up water and drains more slowly when wetted, and packs quite firmly, but without cracking, as it dries. It is an alluvial soil which has a large supply of available phosphoric acid, a medium-high supply of available potash and calcium, but a very small amount of available nitrogen and a low content of organic matter. It has a pH of about 7.2 in the field. This Makiki soil is considered a very "good" cane soil and produces very heavy crops of cane.

Mitcherlich tests of the two soils used in this study gave the following results and indications of their fertility status:

Plant Food	Manoa Soil (pH 5.4) (lbs. per Acre-Foot)	Status	Makiki Soil (pH 7.2) (lbs. per Acre-Foot)	Status
Nitrogen	217	High	28	Low
Phosphoric acid	62	Doubtful	494	Very high
Potash	464	Doubtful	835	High

After removing the surface foot of soil from each field and thoroughly mixing them, each well-mixed soil was then put into large concrete tubs (2′ x 2′ x 2′). It was firmly tamped in the bottom half of each tub in order to prevent excessive leaching and to be more nearly like the soil conditions of the upper two feet of field soil. To the Manoa soil only, a heavy application of raw rock phosphate was made just under the seed before planting. This was done in order to insure an adequate supply of phosphoric acid to the cane which would be growing in this extremely high phosphate-fixing soil.

Varieties: Three cane varieties were chosen: (1) H 109 was selected because of its excellent record when grown on Makiki soil at Makiki and the general knowledge that it has performed well under climatic conditions similar to those at Makiki but has not done well in Manoa and similar climes. (2) Striped Tip was selected because it has performed fairly satisfactorily under conditions like those at Manoa. (3) POJ 2878 was chosen because it was one of the varieties used by Das in his preliminary study, and also because it was thought to be a variety that would perform quite satisfactorily under both Makiki and Manoa conditions.

Planting: In order to insure a full and comparable stand, ten single-eye cuttings of the variety desired were planted in each tub. These were later thinned so as to leave the best six plants for the basic stand. Thereafter all shoots were allowed to grow.

Fertilization: Because the number of containers available was limited, the differential fertilization was given to only one of the varieties that was grown. Hence we supplied the variety POJ 2878 with two levels of fertilization: an amount of nitrogen, phosphoric acid and potash from ammonium sulphate, superphosphate, and muriate of potash respectively, which we knew to be wholly inadequate for optimum growth was supplied every second month to one series of POJ 2878 plants, while an amount of the same materials which we deemed more than fully ample for maximum growth was given every month to a second series of POJ 2878. This same "ample" fertilization was supplied to all series planted with the H 109 and the Striped Tip canes. Actually, the canes that were "amply" fertilized received four times the amount of plant food which was given to those that were "inadequately" fertilized.

All fertilizer applications were made on the surface of the soil and an irrigation was given to put the material immediately into solution. The first application was not made until the cane was two month old since the cane growth was very slow at the start in October and November. Thereafter, the monthly applications were continued until one month before the cane was harvested.

Discussion of the Results

At the age of 14 months the canes were cut off and topped, the millable cane weighed and crushed, and the crusher juice analyzed for the various constituents which we desired to study. The results have been summarized in Tables I to V inclusive which follow. All weights and analyses given are the average of three pots of each treatment. Standard errors are included for the guidance of those who may wish to use them.

Table I gives the average pounds of millable cane harvested from all varieties, soils, and fertilizer differentials when grown at Makiki as compared with the duplicates grown at Manoa. The cane yield differences quite definitely favor the Makiki climate and the average relative yield of cane shows a crop at Makiki that has produced 2.41 times the yield at Manoa. Thus it would appear that 100-ton cane at Makiki, which can easily be produced, would be compatible with 41.5-ton cane at Manoa, which is probably seldom exceeded there. In other words, it would seem that regardless of or in spite of the soil, the variety, or the fertilization which may be given to sugar cane, a climatic handicap can dominate cane yields to such an extent that even the best agriculturist will do well to obtain much more than 40 per cent of a possible Makiki tonnage under the restricted sunlight and lower maximum temperatures that exist in cane-growing regions which are similar to Manoa. In Fig. 1, we offer an excellent example of the relationship that existed between the weekly growth measurements of the variety H 109 on two distinct soil types, and the effective temperature (as measured by day-degrees) at the two locations during the period when these measurements were being made.

When given ample fertilizer, H 109 produced the most, and Striped Tip the least cane under the favorable climatic conditions at Makiki. Both H 109 and Striped Tip were equally able to make use of the poorer conditions at Manoa and they both were apparently slightly better than POJ 2878 there.

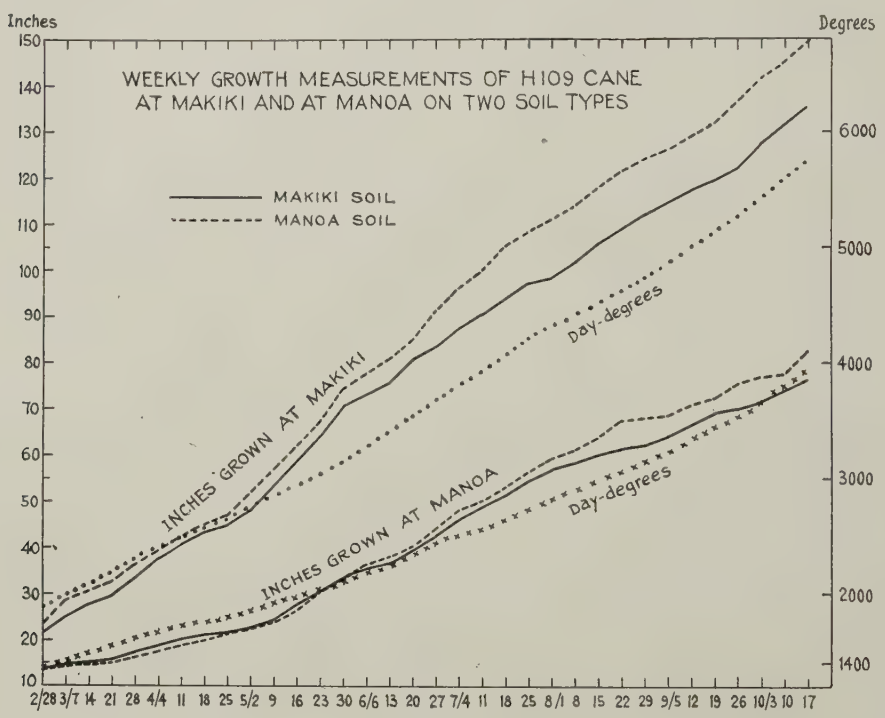

Fig. 1.

We have summarized in Table II the average "yield per cent cane" or pounds of sugar per 100 pounds of cane, in order to show that there was some 29 per cent more sugar per unit of cane produced at Makiki than at Manoa. This evidence of a better quality of cane at Makiki in seven out of the eight comparative combinations of variety, soil, and fertilization, would tend to show that perhaps climate dominates these other factors in determining cane quality as well as in affecting cane yields. It is particularly interesting to note the good quality of 14-month-old cane harvested at Makiki in December, when it is remembered that heavy nitrogen fertilizer applications were made monthly, right up to the time of harvest, and that there was no artificial ripening-off.

Disregarding for the present any difference in soil, both of the amply fertilized H 109 and POJ 2878 canes grown at Makiki had a very similar sugar content, of 12.24 and 11.99 per cent respectively, and both were better than Striped Tip with its 10.75 per cent average. On the other hand, the Striped Tip cane grown at Manoa had a slightly better sugar content than H 109, 9.0 per cent against 8.8, while the correspondingly heavily fertilized POJ 2878 with 8.0 per cent sugar was the least efficient storer of sugar at that location.

TABLE I

THE CANE YIELDS

Variety	Soil	Fert.	Average lbs. millable cane: grown at Makiki	grown at Manoa	Difference favoring Makiki climate: in lbs. of cane	Rel. Diff.
H 109	Maki.	Am.	81.8±3.9	35.4±1.6	46.4±4.3	2.31
"	Man.	"	105.0±3.4	31.5± .8	73.5±3.5	3.33
St. Tip	Maki.	"	44.9±4.2	32.0±1.9	12.9±4.6	1.40
"	Man.	"	71.4±2.8	34.2±2.7	37.2±3.9	2.09
POJ 2878	Maki.	"	69.9±7.3	20.6±5.8	49.3±9.3	3.39
"	Man.	"	87.0±1.0	28.6±3.2	58.4±3.3	3.04
POJ 2878	Maki.	In.	25.4±1.8	17.5±1.6	7.9±2.4	1.45
"	Man.	"	38.2±3.8	16.8± .9	21.4±3.9	2.28
					Average	2.41

Abbreviations used: Var. = variety; Fert. = fertilization; Maki. = Makiki; Man. = Manoa; Am. = amply fertilized; In. = inadequately fertilized

Rel. Diff. = Relative difference or $\frac{\text{Makiki cane yield}}{\text{Manoa cane yield}}$

Note: Averages are presented with their S.E. (Standard Error).

TABLE II

YIELD PER CENT CANE

Variety	Soil	Fert.	Average yield % cane: at Makiki	at Manoa	Equivalent Q.R.'s: at Makiki	at Manoa	Difference favoring Makiki climate: in yield % cane	Rel. Diff.
H 109	Maki.	Am.	12.99± .42	9.53± .46	7.7	10.5	3.46± .62	1.36
"	Man.	"	11.50±1.02	8.07± .80	8.7	12.4	3.43±1.30	1.42
St. Tip	Maki.	"	9.91± .47	10.40± .89	10.1	9.6	−0.49±1.0	.96
"	Man.	"	11.69± .78	7.62± .81	8.5	13.1	4.07±1.13	1.53
POJ 2878	Maki.	"	12.26± .52	8.39±1.38	8.2	11.9	3.87±1.47	1.46
"	Man.	"	11.72± .70	7.60±1.14	8.5	13.2	4.12±1.34	1.54
POJ 2878	Maki.	In.	12.30± .68	12.11± .68	8.1	8.3	.19± .96	1.01
"	Man.	"	11.66± .92	10.91± .25	8.6	9.2	.75± .95	1.07
							Average	1.29

Equivalent Q.R. = "quality ratio" which is the reciprocal of "Yield per cent cane."

Sugar yields are largely influenced by a combination of both cane growth and its sugar content. Under the more favorable Makiki climate, we have produced more than three times the amount of sugar than the less favorable Manoa climate has given us (see Table III). This is the combined result from more cane and a better cane quality at Makiki. Variety comparisons quite clearly indicate that H 109 was able to take best advantage of the favorable conditions, while Striped

Tip was best adapted to deliver sugar from the more restricted amounts of sunlight and temperature received at Manoa. Thus we note further specific and measured evidence of a variety adaptation to climatic differences.

TABLE III

THE SUGAR YIELDS

Variety	Soil	Fert.	Average lbs. sugar: produced at Makiki	produced at Manoa	Difference favoring Makiki climate: in lbs. sugar	Rel. Diff.
H 109	Maki.	Am.	10.63± .68	3.37±.20	7.26± .71	3.16
"	Man.	"	12.14±1.79	2.54±.21	9.60±1.91	4.78
St. Tip	Maki.	"	4.47± .61	3.46±.58	1.01± .84	1.29
"	Man.	"	8.38± .86	2.93±.45	5.45± .97	2.86
POJ 2878	Maki.	"	8.64±1.20	1.87±.68	6.77±1.38	4.62
"	Man.	"	9.34± .71	2.19±.07	7.15± .71	4.27
POJ 2878	Maki.	In.	3.15± .38	2.14±.30	1.01± .48	1.47
"	Man.	"	4.53± .77	1.94±.02	2.59± .77	2.33
					Average	3.10

The influence of climate upon the phosphate and potash concentration in the cane plant, as indicated by the percentages of these mineral elements found in the crusher juice is seen in Table IV. Relatively 19 per cent more phosphate and 50 per cent more potash were found per unit of juice in the canes grown at Manoa, and where adequate fertilization was given there was only one instance out of twelve comparisons where the percentage of these minerals in the juice was less at Manoa than at Makiki.

TABLE IV

PHOSPHATE AND POTASH IN THE CRUSHER JUICE

Variety	Soil	Fert.	Average % P_2O_5 in juice: at Makiki	Average % P_2O_5 in juice: at Manoa	Difference favoring Manoa climate: in % P_2O_5 in juice	Rel. Diff.	Average % K_2O in juice: at Makiki	Average % K_2O in juice: at Manoa	Difference favoring Manoa climate: in % K_2O in juice	Rel. Diff.
H 109	Makiki	Am.	.078	.085	.007±.012	1.09	.18	.22	.04±.02	1.22
"	Manoa	"	.014	.021	.007±.003	1.50	.05	.15	.10±.02	3.00
St. Tip	Makiki	"	.128	.134	.006±.008	1.05	.26	.27	.01±.02	1.04
"	Manoa	"	.046	.061	.015±.005	1.33	.08	.12	.04±.02	1.50
POJ 2878	Makiki	"	.082	.099	.017±0.18	1.21	.31	.27	—.04±.03	.89
"	Manoa	"	.024	.026	.002±.007	1.08	.09	.21	.12±.02	2.33
POJ 2878	Makiki	In.	.137	.123	—.014±.004	.90	.30	.28	—.02±.02	.90
"	Manoa	"	.025	.034	.009±.006	1.36	.08	.09	.01±.01	1.12
						Average 1.19				Average 1.50

Fig. 2. H 109 cane grown with ample fertilization: (at the left) on "good" Makiki soil at Makiki and at Manoa respectively; (at the right) on "poor" Manoa soil at Makiki and Manoa respectively.

TABLE V

CHANGES IN THE SOIL pH

Variety	Soil	Fert.	Original pH	pH of soil at harvest — Cropped at Makiki		pH of soil at harvest — Cropped at Manoa	
H 109	Makiki	Am.	7.2	6.3		6.1	
St. Tip	"	"	"	6.2	6.2	6.1	6.0
POJ 2878	"	"	"	6.1		5.8	
POJ 2878	"	In.	"	7.0		6.6	
H 109	Manoa	Am.	5.4	5.5		5.1	
St. Tip	"	"	"	5.3	5.3	4.8	4.9
POJ 2878	"	"	"	5.2		4.7	
POJ 2878	"	In.	"	6.5		5.5	
		Average	6.3	6.0		5.6	

Table V shows the changes in pH of the soils that occurred while these crops were growing on them. The series grown at Manoa has become more generally acid than the Makiki series. Where the wholly adequate amounts of fertilizer were supplied, we note the following changes: (a) the original pH of 7.2 of the Makiki soil has dropped to 6.2 at Makiki and to 6.0 at Manoa; (b) the original pH of 5.4 of the Manoa soil has changed to 5.3 at Makiki and to 4.9 at Manoa. It is quite

Fig. 3. Striped Tip cane grown with ample fertilization: (at the left) on "good" Makiki soil at Makiki and at Manoa respectively; (at the right) on "poor" Manoa soil at Makiki and Manoa respectively.

likely that the increase in the acidity of these soils has been due to the large monthly applications of ammonium sulphate that were made. At Makiki the difference between a pH of 7.2 and 6.2 in the Makiki soil could be equivalent to an increase of only about 5 active acidity units,* while the difference between the pH of 5.4 and 5.3 for the Manoa soil cropped at Makiki is equivalent to an increase of 10 active acidity units. When these same comparisons are made for the series grown at

* E. T. Wherry (Bull. No. 4, Am. Hort. Society) uses directly related numbers termed "acidity units" which indicate the "active acidity" or the amount of hydrogen ions in the solution that are free to exert the effects commonly classified as acidity. They help us to more clearly visualize what the differences in pH may represent.

Manoa, the increased acidities for the Makiki and Manoa soils were of the nature of 9 and 85 active acidity units respectively, i.e., the acidity of the Manoa soil was increased under the Manoa climate to more than nine times its increased acidity under the Makiki climate.

Other Relationships

In addition to a study of the effects of climate, the data offer an opportunity to note several other interesting relationships.

1. *Soils:* The two soils used in this study were, as has been indicated, quite different both in their physical and original chemical composition. Both soils were fertilized with what was considered to be an abundant supply of plant food (except in one series of treatments) and this was supplied each month the crop was growing. Hence there should have been no real plant food deficiency in either soil.

The results (see Table VI) show that the relative cane yields from the Manoa soil averaged 24 per cent more than from the Makiki soil. However, it will be seen that the Manoa soil at Makiki produced 40 per cent more cane, while on the same soil at Manoa the increase was only 8 per cent over the Makiki soil. Was the better physical condition of the Manoa soil responsible for these gains? Can this better physical condition of a soil be a factor of more importance where superior climatic conditions are available for the production of larger cane crops? Conversely, there would appear to be slightly more sugar per unit of cane (yield per cent cane) for the crops grown on the Makiki soil. Although the individual comparisons do not show yield differences that are large enough to be significant, the fact that seven of these eight comparisons show a higher relative "yield per cent cane" figure in favor of the Makiki soil, would indicate a possible influence of soil on cane quality. We do not know why this should be so. Was this poorer quality from the Manoa soil caused by the heavy application of rock phosphate (with its large calcium content) that we mixed into the surface foot of the Manoa soil in our attempt to insure an adequate supply of phosphate for the cane in this high phosphate-fixing soil; might this poorer quality have been associated with a possibly higher content of calcium and nitrogen in the plant? Was the better quality from the Makiki soil in any way related to the larger percentages of both phosphate and potash that were found in the crusher juices of all the treatments grown on this soil? (Our usual experience has been that the quality is more apt to be inversely related to the percentage of phosphate and potash in the crusher juice.)

The individual differences in the sugar yields produced from comparisons made on these two soils are perhaps not significant amounts, although it may be significant that we find the Manoa soil netted considerably more sugar when the cane was grown thereon under the favorable climatic conditions at Makiki.

2. *Varieties:* In addition to what has already been said about the varieties studied in this test, the comparisons as arranged in Table VII are of interest.

H 109 was superior to both POJ 2878 and Striped Tip at both Makiki and Manoa, and yet it was apparently a more economic user of both phosphate and potash. POJ 2878 was better than Striped Tip when grown at Makiki but the reverse was true when these two varieties were compared at Manoa. The POJ 2878 took up less phosphate but more potash than the Striped Tip.

TABLE VI

EFFECTS SECURED FROM DIFFERENT SOILS

Variety	Grown at	Fert.	Difference favoring Manoa soil: in lbs. cane	Rel. Diff.	Difference favoring Makiki soil: in yield % cane	Rel. Diff.	Difference favoring Manoa soil: in lbs. sugar	Rel. Diff.	Difference favoring Makiki soil: in P_2O_5 in juice	in K_2O in juice
H 109	Makiki	Am.	23.2±5.2	1.28	1.49±1.10	1.13	1.51±1.91	1.14	.064	.13
"	Manoa	"	— 3.9±1.8	.89	1.46± .92	1.18	— .83± .29	.76	.064	.07
St. Tip	Makiki	"	26.5±5.1	1.59	—1.78± .91	.85	3.91±1.06	1.88	.082	.16
"	Manoa	"	2.2±3.3	1.07	2.78±1.20	1.37	— .53± .73	.85	.073	.15
POJ 2878	Makiki	"	17.1±7.4	1.24	0.54± .87	1.14	.70±1.39	1.08	.058	.22
"	Manoa	"	8.0±6.6	1.39	.79±1.79	1.10	.32± .68	1.17	.073	.06
POJ 2878	Makiki	In.	12.8±4.2	1.50	.64±1.14	1.06	1.38± .86	1.44	.112	.22
"	Manoa	"	— 0.7±1.8	.96	1.20± .72	1.11	— .20± .30	.91	.089	.19
	Averages		10.6	1.24	.90	1.12	.78	1.15	.077	.15
	Significance		Odds 60:1		Odds 20:1		Odds 9:1			

	Average Rel. Diff. (favoring Manoa soil)	Average Rel. Diff. (favoring Makiki soil)	Average Rel. Diff. (favoring Manoa soil)
Grown at Makiki	1.40	1.05	1.38
Grown at Manoa	1.08	1.19	.92

Fig. 4. POJ 2878 cane grown with ample fertilization: (at the left) on "good" Makiki soil at Makiki and at Manoa respectively; (at the right) on "poor" Manoa soil at Makiki and Manoa respectively.

TABLE VII

RELATIVE DATA CONCERNING VARIETIES

		Grown at	Soil	Yield % Cane	Yield % Sugar	P_2O_5 in Juice	K_2O in Juice
a.	Relative yield	Makiki	Makiki	1.17	1.06	1.23	.95	.58
		Makiki	Manoa	1.21	1.08	1.30	.58	.56
	H 109	Manoa	Makiki	1.72	1.14	1.80	.86	.82
	POJ 2878	Manoa	Manoa	1.10	1.06	1.22	.81	.71
			Average	1.30	1.08	1.39	.80	.67
b.	Relative yield	Makiki	Makiki	1.82	1.31	2.38	.61	.69
		Makiki	Manoa	1.22	.99	1.45	.30	.63
	H 109	Manoa	Makiki	1.12	.92	.98	.63	.82
	St. Tip	Manoa	Manoa	.84	1.06	.87	.34	1.25
			Average	1.25	1.07	1.42	.47	.85
c.	Relative yield	Makiki	Makiki	1.56	1.24	1.93	.64	1.19
		Makiki	Manoa	1.22	1.00	1.11	.52	1.12
	POJ 2878	Manoa	Makiki	.64	.81	.54	.74	1.00
	St. Tip	Manoa	Manoa	.84	1.00	.75	.43	1.75
			Average	1.07	1.01	1.08	.58	1.27

TABLE VIII

RELATIVE EFFECT OF INCREASED FERTILIZATION ON POJ 2878

	Grown at	Soil	On Yield On Cane	On Yield % Cane	On Yield On Sugar	On P_2O_5 in Juice	On K_2O in Juice
Relative yield	Makiki	Makiki	2.75	1.00	2.74	.60	1.03
	Makiki	Manoa	2.28	1.00	2.06	.96	1.12
Ample fertilization	Manoa	Makiki	1.18	.69	.87	.80	.97
Inadequate fertilization	Manoa	Manoa	1.70	.70	1.13	.77	2.33
		Average	1.98	.85	1.70	.78	1.36

3. *Fertilization:* A glance at Table VIII will show that when POJ 2878 was given an ample supply of fertilizer on either soil type used, a gain in yield of cane and sugar over the inadequately fertilized series was quite evident. Such gain, however, was much greater when the cane was grown at Makiki, and hence we have further evidence that the limiting growth factor at Manoa was quite likely climatological.

It is of special interest to note that the heavier fertilization did not affect the

Fig. 5. POJ 2878 cane grown with inadequate fertilization: (at the left) on "good" Makiki soil at Makiki and at Manoa respectively; (at the right) on "poor" Manoa soil at Makiki and Manoa respectively.

quality of the POJ 2878 cane that was grown at Makiki. On the other hand, the quality of the cane grown at Manoa was adversely affected by the large fertilizer applications. Thus it may be argued that under those conditions where sunlight is limited and temperatures are low, too much fertilizer may quite likely result in a poor cane quality, but where these climatic factors are not apt to be limiting growth factors, the same degree of concern about poor juices resulting from heavy fertilization need not be necessarily felt.

Conclusion

This study of the effect of climate upon cane and sugar yields has given us further evidence of the dominating influence that climatic factors can have upon our field results. When we disregard the soil, variety, and fertilization differences, it would appear that we may expect at Manoa, where temperatures are lower and skies quite apt to be overcast throughout a large part of the growing period, only about one-third as much sugar as from the Makiki area that is more favorably situated. However, this effect is apparently subject to some improvement, especially when advantage may be taken of the ability of some cane variety to utilize the limited light and heat conditions more efficiently.

It would also appear that perhaps some soil condition, probably physical, might be modified in such a way that a greater efficiency would be secured from different climatic environments. The closer grained Makiki soil produced 8 per cent more sugar at Manoa than the more granular, open type of Manoa soil; conversely, this loose, granular Manoa soil was 38 per cent better than the more compact Makiki soil, when it was cropped at Makiki.

Certainly we will have to recognize that cane which is being grown under unfavorable climatic influences cannot be given the excess of available plant food, without suffering a poorer quality, that it is possible to give to cane that is growing where there is little or no limiting growth-effect due to climate.

Rat Control Investigations at The Lihue Plantation Company, Ltd.

By Thomas G. Eckart

Introduction

Many steps have been taken during the past few years to improve the poison bait methods of rat control throughout the Territory. A great deal of outstanding work has been done by Pemberton, Barnum and Doty of the Experiment Station, H. S. P. A., and their pioneering in poisoned grain baits is the backbone of the recent investigations at The Lihue Plantation Company, Limited. A great deal of credit must be given these men for the foundation they laid.

Everyone realizes that rats are carriers of disease, and that rats do a certain amount of damage. How many of us have stopped to figure out rat damage in dollars and cents, and how many of us realize what a negligible expense proper rat control is compared to the savings resulting from that control?

The purpose of this paper is not only to point out the value of rat control but also, to briefly summarize the recent poison bait studies* conducted at The Lihue Plantation Company, Limited, and the changes in control policy resulting from these studies.

The Value of a Dead Rat

According to the joint statements of the United States Chamber of Commerce and the Bureau of Biological Survey, rats and mice do approximately five hundred million dollars damage annually in the United States, each rat doing damage to the extent of at least two dollars. "Tests of captive rats show that every rat will consume sixty pounds of grain or other foodstuffs in the course of a year" (1).

It is a well-known fact that rats in sugar cane fields destroy a great deal more cane than they actually eat. Rat-eaten cane stalks sour and decay and if the damage is at all severe the result is a decreased cane tonnage and poor juices. To growers of sugar cane a dead rat is worth several times more than two dollars, but in arriving at "The Value of a Dead Rat" there is another factor to be considered besides the actual damage done today. Rats breed four or five times a year and each litter consists of from 6 to 10 young, divided equally as to sexes. A pair of rats may thus produce a large progeny in a year (2). Theoretically then, a dead rat is worth a great deal more than two dollars.

Rats At Lihue

The common rat of Lihue fields is the gray rat, *Rattus norvegicus* (Erxlelen), reported as being the most difficult species to control.

During the 1935 harvesting season of The Lihue Plantation Company, Lim-

* Detailed counts have been omitted from this paper. Only final summaries are presented.

ited, 90,664 rats were caught in the harvest fields of the Lihue and Hanamaulu divisions and 10,248 were caught elsewhere on the plantation—a total of 100,912 rats. These rats were caught by two men who, with a shovel and a pack of dogs each, followed the loading machines through the harvest fields of the two divisions named. These men were paid by the day and by the rat tail. The 100,912 rats represented an investment of not over $1,500.00 and a saving of $201,824.00 at two dollars a rat. If these rats each did damage only to the extent of two cents, the money spent was still very worth while.

A total of 330,256 rats have been caught in the harvest fields of the Lihue and Hanamaulu divisions during the past seven years. A total of 115.5 *tons* of rats—worth at least $660,512.00 to the plantation and representing an investment of not over $8,000.00.

In the harvest fields of the Lihue division, where rats are very numerous because of the many stone walls, an average of 31.2 rats per acre of harvested cane was caught in 1935. The Hanamaulu harvest fields, during the same period, yielded an average of 10.3 rats per acre. Some rats are killed in "burning off"—a great many escape to adjacent fields and near-by stone walls and rock piles—so the average number of rats caught is a mere fraction of the population per acre. The difference in the above per acre averages is due, not only to the stone walls and rock piles of the Lihue division, but also to the difference in efficiency of the two rat men and their dogs and differences in poison bait control.

A record of the rats caught per day provides a means of studying rat population, and permits giving special poison bait attention to badly infested areas during the progress of the following crop. Besides, the rats caught in specific fields year after year provide a fair index of poison bait control efficiency.

Objectives

The poison bait studies recently completed at The Lihue Plantation Company, Limited, were planned and conducted with the following objectives:

(1) To arrive at an "effective take" or "kill" index, in terms of amounts consumed, for grain baits treated with various amounts of thallium sulphate.

(2) To study various poison carriers and vegetable oils in the hope of finding a bait of outstanding rat acceptance.

(3) To study the amounts of improved bait eaten per unit of time with the plan of adjusting the thallium sulphate concentration to secure a maximum kill.

Effective Take

Thallium-sulphate treated wheat (one pound of thallium sulphate to 1000 pounds of wheat), prepared by the Pacific Guano and Fertilizer Company, made up into waterproof (paraffin dipped) torpedoes has been used on this plantation for several years. A great many distributed torpedoes always remained untouched or slightly nibbled and we began to wonder just how effective our poison bait

control was. Recent studies by Garlough* show 30 mg/kg to be a lethal thallium sulphate dose for rats disregarding possible food effects. A lethal dose for a large rat then, weighing 350 grams, under laboratory conditions,† is 10.48 mg. of thallium sulphate. At a ratio of one pound of thallium sulphate to 1000 pounds of wheat an average Lihue torpedo, weighing 9 grams, contained 9 mg. of thallium sulphate—only enough to kill small and medium-sized rats and mice providing they ate the entire torpedo or a very large portion of it. Very few torpedoes were eaten entirely—less than 10 per cent consumed to the extent of 50 per cent or more. The old, wheat torpedoes were not only too weak, they were not particularly attractive as a food.

The thallium sulphate concentration of whole wheat was doubled during 1935. Theoretically, a half of a whole wheat torpedo of this new strength should kill small and medium sized rats. A cage test in which 12 rats of various sizes were kept in separate cells, showed that half of one of these more powerful torpedoes would kill the small and medium sized rats but not the largest.

Early in 1936, when Lihue changed from whole wheat to rolled barley, the thallium sulphate concentration was again increased (one pound of thallium sulphate to 333 pounds of barley). Rolled barley is approximately 33 per cent lighter than whole wheat per unit volume and besides—rats do not eat the hulls. The average Lihue rolled barley torpedo weighs 6½ grams and contains 3.09 mg. of thallium sulphate per gram. Half of one of these barley torpedoes, then, is theoretically sufficient to kill any rat. Repeated cage tests using the new barley of increased thallium sulphate strength showed half a torpedo sufficient to kill rats of all sizes.

W. P. Alexander, Assistant Manager of Grove Farm Company, Limited, reports that missing torpedoes are generally entirely consumed. This he discovered by tying long strings to torpedoes and carefully retrieving the remains (generally paper shells) of those which were missing.

Throughout this investigation the 1 to 500 and 1 to 333 thallium sulphate concentrations were used. Reference to effective take means torpedoes which have been consumed to the extent of 50 per cent or more—or those which are missing. For the weaker of the two concentrations (one pound of thallium sulphate to 500 pounds of grain) the effective take is not absolutely true, as 50 per cent of a torpedo was not sufficient to kill all rats, but may be considered true for the experiments here discussed without appreciably affecting the results.

Corn Oil

Doty (3) (4) found an increase in take, at the Kailua Substation of the Experiment Station, H. S. P. A., by dipping torpedoes in corn oil. Experiments to study the effect of corn oil on wheat torpedoes were planned and set out. Our results corresponded closely to those obtained by Doty.

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* F. E. Garlough—now conducting rat investigations throughout the Territory.

† A rat diet under field conditions may have some effect on the killing power of thallium sulphate.

FIELD 5W HM.

	Effective Take*—Per Cent			
	Test No. 1		Test No. 2	
	2 days	4 days	2 days	4 days
Corn-oil dipped	60.5	71.4	71.2	75.4
Corn-oil sprayed	26.3	42.9	58.5	63.1
Untreated†	10.5	26.2	47.7	50.8

* Effective take varies with rat population and therefore can *only* be compared within an experiment.

† The effective take of untreated wheat in these tests is extremely high due to an unusually large rat population in the area.

Tests conducted in other areas gave the same conclusive results. Corn-oil dipping was then made a standard plantation practice and other bait studies were commenced.

Grain Preference

Reports of other investigators in the Territory and elsewhere to the effect that rats preferred rolled barley to wheat led to grain preference studies. Twelve healthy field rats (6 large and 6 medium sized) were placed in separate cages. Glass jars containing the following materials were placed in each cell.

1—Water
2—Barley (rolled)
3—Sunflower seed
4—Corn (cracked)
5—Wheat (whole)
6—Soybeans

The containers were not refilled. As the rats consumed the contents of one jar they were obliged to make a second choice, etc. In each cage all the rolled barley was thoroughly consumed first—only hulls remained. Second choice was a draw between sunflower seed and cracked corn. Third choice was wheat and the rats became very hungry before they touched it. The soybeans remained untouched and because the purpose of the test was fulfilled the rats were destroyed. This test was repeated with identical results; however, before changing our plantation practice from poisoned wheat to poisoned barley, further studies, under field conditions, were desired.

Corn Oil Inside and Out vs. Corn Oil Outside Only

It seemed logical that if rats liked corn oil and they do, that they would eat more of a torpedo if the grain were saturated with corn oil. Doty (4) found at Kailua that "as long as the torpedo was dipped in corn oil, it made no difference whether the wheat contained corn oil or not." Field experiments were then installed to check Doty's findings, with the following results:

EXPERIMENT NO. 5—FIELD 5W HM.—96 STATIONS

	1 torpedo of each kind per station Effective Take—Per Cent			
	2½ days	5½ days	7½ days	9½ days
Standard Wheat no oil	3.1	3.0	3.0	3.1
Wheat—Corn oil outside only	17.7	21.0	21.2	20.4
Wheat—Corn oil inside and out	22.9	33.0	34.3	34.7
Barley—Corn oil outside only	12.5	18.0	20.2	20.4
Barley—Corn oil inside and out	30.2	35.0	42.4	40.8

A marked increase in effective take is shown for "corn oil inside and out" over "corn oil outside only." Rolled barley was preferred to wheat where the grain was saturated with corn oil but there was no significant difference between wheat and barley with "corn oil outside only."

Raw Linseed Oil vs. Corn Oil — Barley vs. Wheat

To compare raw linseed oil with corn oil, and whole wheat with rolled barley torpedoes the following experiment was installed:

EXPERIMENT NO. 6—FIELD 5 HM.—73 STATIONS

	1 torpedo of each type per station Effective Take—Per Cent			
	1½ days	3½ days	5½ days	11 days
Wheat—Raw linseed oil inside and out	35.6	41.1	45.1	47.8
Barley—Raw linseed oil inside and out	34.2	50.7	52.1	79.1
Wheat—Raw linseed oil outside only	30.1	37.0	38.0	37.3
Barley—Raw linseed oil outside only	19.2	24.7	28.2	32.8
Wheat—Corn oil inside and out	19.2	24.7	23.9	31.3
Barley—Corn oil inside and out	28.8	37.0	40.8	47.8
Wheat—Corn oil outside only	11.0	11.0	12.7	17.9
Barley—Corn oil outside only	12.3	12.3	9.9	16.4
Wheat, no oil	8.2	12.3	11.3	11.9

Under the conditions of this test the rats showed an outstanding preference for "barley-raw linseed oil inside and out."

It is interesting to note that wheat has the edge over barley when the oil is outside only, but that barley is far superior to wheat when the oil is inside and out. The same trend exists in Experiment No. 5.

Both Experiments No. 5 and No. 6 might be classed as "skirmish" tests or "feeler" tests because of the numerous variables per station. The effectiveness of the various torpedoes might be quite different in a test where one station contained several of only one type of torpedo. In these two tests the rats not only had a choice between the various baits but having been attracted by an oil they may have eaten several torpedoes regardless of type to satisfy their hunger. The two tests, however, gave very good indications as to what baits were preferred thus eliminating those which we might class as "not so good," and permitting a better test of fewer variables.

Experiment No. 7 which is summarized below, was planned to compare: wheat torpedoes not treated with oil (the standard torpedo of past years) with "wheat-

corn oil outside only" (our recently declared standard) with "wheat*-raw linseed oil inside and out" (the second most effective torpedo type of Experiment No. 6). Two torpedoes of one type only were placed in a station to eliminate the possible effect on take that one torpedo type may have on another.

EXPERIMENT NO. 7—FIELD 1W AND 5W HM.—93 STATIONS

	2 torpedoes of one type per station Effective Take—Per Cent	
	5½ days	9½ days
Wheat—Raw linseed oil inside and out	37.1	47.8
Wheat—Corn oil outside only	31.7	48.9
Wheat, no oil	7.5	10.8

The results show no difference, under the conditions of this test, between "wheat-raw linseed oil inside and out" and "wheat-corn oil outside only." The very poor effective take of the old wheat standard (no oil) is quite apparent.

Experiment No. 10 was designed to study "barley-raw linseed oil inside and out" (outstanding in Experiment No. 6 in comparison with "barley-raw linseed oil outside only.")

EXPERIMENT NO. 10—FIELDS 18 L, 9 HM, AND 30 M—131 STATIONS

	2 torpedoes of one type per station Effective Take—Per Cent
	3 days*
Barley—Raw linseed oil inside and out	86
Barley—Raw linseed oil outside only	69

* Heavy rains washed out many torpedoes and prevented further counts.

The results of this test show a good increase in take for "barley-raw linseed oil inside and out" over the "barley-raw linseed oil outside only."

Based on the data collected to date the plantation practice was changed from "wheat-corn oil outside only" to "barley-raw linseed oil outside only."

Effects of Putting Oil Inside Paraffin-Dipped Torpedoes

Observation has shown that when grain is soaked with oil and made up into torpedoes the paper generally becomes impregnated with oil and as a result the hot paraffin, used for water proofing, as well as strengthening, passes into the torpedo.† This is an undesirable feature because paraffin is undigestible and grain coated with paraffin may pass through the system of a rat without effect. The use of an inexpensive but strong wax paper for wrapping will eliminate this problem and at the same time result in reduced costs.

Before standardizing on "barley-raw linseed oil inside and out," the following questions remained to be answered:

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* No thallium sulphate treated barley on hand.

† It has been noticed in using cocoanut oil that the paraffin enters the torpedo where the paper is oil impregnated but flakes off the grain rather than adhering to it. By carefully limiting the oil to 1 pint per 5 pounds of grain and at the same time using 3 sheets of tissue per torpedo the entrance of paraffin is cut to a minimum.

(1) What effect, if any, does the inward passage of paraffin have on the killing effectiveness of torpedoes?
(2) Is the killing effectiveness of grain altered by an oil coating?

To answer these questions cage experiments were conducted. A total of 12 healthy field rats (6 large and 6 medium) housed in separate cells were each given ½ of a "barley torpedo-raw linseed oil inside and out." The oil-treated bait containing the usual quantity of paraffin which passes through oil-impregnated paper proved quite effective with the killing, accompanied by symptoms of thallium sulphate poisoning, of 5 of the 6 medium and 4 of 6 large sized rats.* Shortly after the completion of this experiment the Pacific Guano and Fertilizer Company increased the thallium sulphate concentration of rolled barley. The experiment was duplicated and every rat died of thallium poisoning.

To saturate the poisoned rolled barley with raw linseed oil before making up torpedoes and then dipping in raw linseed oil would be quite worthwhile as compared to dipping alone, but other grains might be superior to rolled barley and other oils superior to raw linseed oil. Before making further changes in our standard practice it was decided to carry on further tests, to try all likely grains and oils and then select the best as a standard practice.

Raw Linseed Oil vs. Cocoanut Oil

Experiment No. 16 compares poisoned "barley-cocoanut oil outside only" with poisoned "barley-raw linseed oil outside only." Two torpedoes of each type were placed in alternate stations to eliminate the attraction effect that one torpedo type might have on another. The test of 190 stations was laid out in three localities. In making counts, all torpedoes except those untouched were replaced. The results are summarized as follows:

EXPERIMENT NO. 16—FIELD 18 L—66 STATIONS

	Effective Take—Per Cent		
	2 days	5 days	8 days
Barley—Cocoanut oil outside only.....	65.2	80.3	71.2
Barley—Raw linseed oil outside only.....	86.4	84.8	72.7

FIELD 30 M—88 STATIONS

	Effective Take—Per Cent	
	2 days	5 days
Barley—Cocoanut oil outside only.....	76.1	9.1
Barley—Raw linseed oil outside only.....	45.5	3.4

FIELD 5 HM—36 STATIONS

	Effective Take—Per Cent	
	2 days	5 days
Barley—Cocoanut oil outside only.....	22.2	11.1
Barley—Raw linseed oil outside only.....	19.4	0

* Thallium sulphate concentration of 1 to 500. Refer to page 159.

GRAND SUMMARY—190 STATIONS

	Effective Take—Per Cent	
	2 days	5 days
Barley—Cocoanut oil outside only	62.1	34.2
Barley—Raw linseed oil outside only	54.7	31.1

The extent of the decrease of per cent effective take from the first observation to the second, etc., is an indication of extent of rat population in the area concerned and may be used as a good indication of poison bait preference. The rat population in field 18 L, for example, is known to be unusually large both through observation on the present damage in the field and by the number of rats caught during past harvests in that field and in adjacent fields. The torpedoes set out each time were not enough to satisfy the rat population of the immediate area with the result that the per cent effective take remained very high for the three counts. In fields 30 Makee and 5 Hm. the rat populations are known to be small, particularly in the immediate areas of the tests, and the first sets of torpedoes were sufficient to kill most of the rats. In consequence all but a few of the replaced torpedoes were untouched and the second count showed a marked decrease in effective take for all torpedoes. In field 18 Lihue there were too many rats per bait to allow complete selection. Had the test been carried on for several more counts a point would have been reached with the killing off of the population, where there would be enough baits per rat to allow selection. Unfortunately a scarcity of time prevented further counts in this field. In field 30 Makee and 5 Hm., where the rat populations are small, bait selection was possible and probably occurred. Following this line of reasoning, the true value of the various types of torpedoes must be learned from experiments of this nature where all torpedoes are replaced at each count, and the sum total of effective take of all observations for each type of torpedo is a far more accurate indication of a torpedo's worth than the effective take of individual observations. The following table summarizes this experiment accordingly:

GRAND SUMMARY

	Total Torpedoes Effective
	5 days
Barley—Cocoanut oil outside only	183
Barley—Raw linseed oil outside only	162

This summary shows a questionable preference for "barley-cocoanut oil outside only," to "barley-raw linseed oil outside only." The difference is too small to be significant because of the probable error involved in the count and in the effectiveness of the torpedoes missing. Perhaps the surest way of arriving at rat preference for the two oils used in this test is to study the total number of torpedoes untouched.

	Torpedoes Untouched
Barley—Cocoanut oil outside only	77
Barley—Raw linseed oil outside only	72

Here again the difference is too small to be significant. It might be concluded,

then, that under the conditions of this test, cocoanut oil is just as attractive to rats as raw linseed oil.

Barley-Cocoanut Oil Inside and Out vs. Barley-Cocoanut Oil Outside Only

With Experiment No. 16 showing that cocoanut oil appeals to rats to about the same extent as raw linseed oil, the next step was to see if the effective take could be increased by soaking barley in cocoanut oil before making up the torpedoes and dipping. Cocoanut oil is less expensive than raw linseed oil—a fact of interest to all.

Experiment No. 17 compares "barley-cocoanut oil inside and out" with "barley-cocoanut oil outside only." Two torpedoes of one type were placed in alternate stations. The test including 310 stations was laid out in three different places. In making counts, all torpedoes except those untouched were replaced. The results are tabulated below:

EXPERIMENT NO. 17—FIELD 30 M—94 STATIONS

	Effective Take—Per Cent	
	3 days	6 days
Barley—Cocoanut oil outside only.....	42.6	25.5
Barley—Cocoanut oil inside and out.....	61.7	56.4

FIELD 4W HM.—68 STATIONS

	Effective Take—Per Cent	
	3 days	6 days
Barley—Cocoanut oil outside only.....	27.9	13.2
Barley—Cocoanut oil inside and out.....	35.3	13.2

FIELD 1W HM.—148 STATIONS

	Effective Take—Per Cent	
	3 days	6 days
Barley—Cocoanut oil outside only.....	28.4	22.3
Barley—Cocoanut oil inside and out.....	33.1	31.1

GRAND SUMMARY

	Effective Take—Per Cent	
	3 days	6 days
Barley—Cocoanut oil outside only.....	32.6	21.3
Barley—Cocoanut oil inside and out.....	42.3	34.8

The results show a significant increase in effective take for "barley-cocoanut oil inside and out." The significance of the results is brought out very clearly in a study of the total number of torpedoes effective during the 6-day period:

GRAND SUMMARY

	Total Torpedoes Effective
	6 days
Barley—Cocoanut oil outside only.....	167
Barley—Cocoanut oil inside and out.....	239

Another Skirmish Test

In order to study rat preference for oils in combination and various prospective balanced diets, this skirmish test was installed. The torpedoes were grouped in such a manner as to allow, at the same time, a study of rat preference for the "outside" oils used.

The test was installed in field 30 Makee and one group (three torpedoes of each type) was placed per station, that is: three baits of each type of group A were placed in Station 1, and three baits of each type of group B were placed in Station 2, etc. A total of 224 stations were set out 7 feet apart. The observation summarized below was made 4 days later.

Group:		Per Cent Effective Take	Per Cent Untouched
A	Barley—Cocoanut oil inside and out	30	49
	Barley—Cocoanut oil inside and raw linseed oil outside	41	33
B	Rolled Oats*—Cocoanut oil inside and out	49	40
	Rolled Oats*—Cocoanut oil inside and raw linseed oil outside	68	15
C	Barley(10)†—Coco Meal(2)‡—Cocoanut oil(½)—Cocoanut oil outside	25	61
	Barley(10)†—Coco Meal(2)‡—Cocoanut oil(½)—Raw linseed oil outside	40	30
D	Rolled Oats(10)—Coco Meal(2)—Coco oil(½)—Cocoanut oil outside	53	31
	Rolled Oats(10)—Coco Meal(2)—Coco oil(½)—Raw linseed oil outside	65	20
E	Barley(7)—Rolled oats(2)—Coco meal(1)—Coco oil(½)—Cocoanut oil outside	35	46
	Barley(7)—Rolled oats(2)—Coco meal(1)—Coco oil(½)—Raw linseed oil outside	48	30
F	Barley(2)—Hamburger(1)—Cocoanut oil outside	27	51
	Barley(2)—Hamburger(1)—Raw linseed oil outside	32	39
G	Barley—Linseed oil inside—Cocoanut oil outside	10	47

* Not poisoned.
† Parts by volume.
‡ Not extracted.

The results of this test show a marked rat preference for the "cocoanut oil inside-raw linseed oil outside" oil combination. There is also shown an outstanding preference for rolled oats over barley. The rolled oat torpedoes were made up of poison-free grain as no thallium sulphate treated rolled oats were on hand. The lack of poison on the grain may play a large part in the rolled oat preference shown in the results. The test was conducted as a "feeler" with the hope of finding a lead on which to concentrate.

The increase in effective take of rolled oats over rolled barley may be outweighed by the additional cost per unit of grain. A pound of poisoned rolled oats may kill a few more rats than a pound of poisoned barley, but a dollar's worth of poisoned barley may kill more rats than a dollar's worth of poisoned oats.

The barley-hamburger mixture was not particularly attractive to the rats. The paraffin dipping, necessary to prevent breakage, prevented the exit of the meat

odor, and so the torpedoes were dipped, some in cocoanut oil and some in raw linseed oil, to give them the same odor as the other torpedoes being tested.

The results for group "E" indicate that the addition of a small part of rolled oats to the barley bait, "cocoanut oil inside-raw linseed oil outside," may result in a maximum effective take per unit cost.

Rolled Oat-Rolled Barley Proportions-Cocoanut Oil Inside-Raw Linseed Oil Outside vs. Rolled Barley-Cocoanut Oil Inside-Raw Linseed Oil Outside

"Barley-cocoanut oil inside-raw linseed oil outside" is preferred to "barley-cocoanut oil inside and out," the bait outstanding until the last "feeler" test. Rolled oats have been shown to be preferred to barley with the possibility of a very desirable barley-rolled oat mixture which if as effective as rolled oats alone would be a more economical bait because of the large difference in the price of the two grains.

Experiment No. 18 was designed to make a final study of the "cocoanut oil inside-raw linseed oil outside" oil combination and to study rolled oat (unpoisoned) and rolled barley proportions. The experiment was installed in three places throughout the Wailua Homestead region. Two torpedoes of one type only were placed in a station. The stations, 680 in number, were marked by fence posts from 4 to 7 feet apart. In making counts, all torpedoes except those untouched, were replaced. The results (all areas combined) are summarized below:

	Effective Take—Per Cent	
	2 days	4 days
Oats—Cocoanut oil inside—linseed oil outside	82.9	46.8
Barley—Cocoanut oil inside and out	64.7	10.4
Barley—Cocoanut oil inside—linseed oil outside	60.6	4.5
Barley(5)*—Oats(1)—Coco oil† inside—linseed oil outside	71.2	17.5
Barley(5) —Oats(2)—Coco oil inside—linseed oil outside	81.2	32.5
Barley(5) —Oats(3)—Coco oil inside—linseed oil outside	81.8	15.6
Barley(5) —Oats(4)—Coco oil inside—linseed oil outside	86.5	14.9
Barley(5) —Oats(5)—Coco oil inside—linseed oil outside	79.8	21.7

* Parts by volume.

† Cocoanut oil.

	Total Torpedoes	
	Effective	Untouched
Oats—Cocoanut oil inside—Linseed oil outside	213	35
Barley—Cocoanut oil inside and out	126	97
Barley—Cocoanut oil inside—Linseed oil outside	110	122
Barley(5)*—Oats(1)—Coco oil† inside—linseed oil outside	148	81
Barley(5) —Oats(2)—Coco oil inside—linseed oil outside	188	41
Barley(5) —Oats(3)—Coco oil inside—linseed oil outside	163	72
Barley(5) —Oats(4)—Coco oil inside—linseed oil outside	170	72
Barley(5) —Oats(5)—Coco oil inside—linseed oil outside	167	60

* Parts by volume.

† Cocoanut oil.

The results of this test show a rat preference for the rolled oat bait with the "barley (5)-oats (2)" mixture a close second. A study of the total torpedoes

effective and those untouched shows these baits greatly preferred to the others included in the test. The "barley (5)-oat (2)" mixture is the less expensive of the two and may account for just as many dead rats per unit cost. The rats and mice of this locality show a slight preference for the "barley-cocoanut oil inside and out" over the "barley-cocoanut oil inside-raw linseed oil outside."

Rolled Barley (5) Rolled Oats (2) Cocoanut Oil Inside Raw Linseed Oil Outside vs. Various Meat Baits (Sausage)

Various meat baits (sausage), prepared by Garlough, have been used in the pineapple fields of Lanai with very good success. Four types of Garlough's baits containing specific amounts of fresh hamburger, cracked barley alone or in combination with ground copra, thallium sulphate and macadamia nut oil, and packed in sausage skins, were set out in a test for a comparison with one of the outstanding grain baits, "rolled barley (5)-rolled oats (2) cocoanut oil inside-raw linseed oil outside." A total of 180 baits of each type were set out; two of one type only per station. Bait replacements were not made. The results of the test are summarized below:

EXPERIMENT NO. 19—FIELD 30 MAKEE—450 STATIONS

	Effective Take—Per Cent	
	24 hours	3 days
Meat bait No. 114	31	44
Meat bait No. 117	55	66
Meat bait No. 118	40	52
Meat bait No. 119	37	48
Lihue grain bait	30	66

The meat baits were comparatively small and also darker in color than the grain bait and in consequence they were very difficult to relocate. In any number of cases they were carried away and partly eaten by ants, roaches and other insects. Many baits reported missing at the first count were found during the second count. The per cent effective takes for the meat baits are not absolutely true because of the large probable error involved. The grain torpedoes, on the other hand, are large and white and consequently easy to find and are too heavy to be moved by ants, roaches and other insects. The effective take for the grain torpedoes, therefore, is very accurate—the probable error small.

A study of the number of torpedoes untouched after 3 days' exposure is interesting:

	Total Torpedoes Untouched
Meat bait No. 114	100
Meat bait No. 117	62
Meat bait No. 118	85
Meat bait No. 119	93
Lihue grain bait	2

Increased Thallium Sulphate Concentration For Maximum Kill

While these poison bait experiments were being conducted it was noticed in observations 18 to 24 hours after setting out the improved oiled grain torpedoes

that the rats and mice had done a great deal of nibbling, had chewed many oily paper tops, and had eaten torpedoes to the extent of 25 per cent and more. The largest effective take, however, occurred during the 24 to 48 hour period. Did the rat that ate 25 per cent the first night come back for more the second night? If not, the rat may have been large enough and strong enough to pass off the poison contained in its small meal of ¼ torpedo. Had the 25 per cent eaten torpedoes been effective in Experiment No. 19 the per cent effective take for the Lihue grain bait would have been 86 per cent instead of 66 per cent and very small rats and mice would have been killed by fair-sized nibbles.

The efficiency of the newer baits can only reach a maximum by increasing the thallium sulphate concentration to about one pound per 100 pounds of grain. A quarter of a torpedo would then be a lethal dose for all rats, and fair-sized nibbles would kill small-sized rats and mice. Thallium sulphate is very expensive and the increase in kill may not be large enough to offset the additional cost. Whether or not the additional thallium sulphate would have any effect on the attractiveness of the bait remains to be determined.

The plantation practice of "rolled barley-raw linseed oil outside only" has been changed to "rolled barley-cocoanut oil inside-raw linseed oil outside." Effective take per unit cost of the better baits is being investigated and the bait which gives the greatest kill per dollar will be adopted as a standard at Lihue.

Summary

A rat does damage to the extent of at least two dollars to sugar cane in the course of a year.

The rat problem at The Lihue Plantation Company, Limited, is discussed.

The value of catching rats in the harvest fields is pointed out.

"Effective take" of poison baits is discussed.

The acceptance of whole wheat torpedoes is greatly increased by corn oil dipping.

Corn oil dipping was adopted as a standard practice at Lihue.

"Whole wheat torpedoes-corn oil inside and out" are preferred by rats to "whole wheat torpedoes-corn oil outside only."

Rats prefer rolled barley to whole wheat.

Rats do not eat the hulls of rolled barley.

Rolled barley is 33 per cent lighter than wheat per unit volume.

"Rolled barley torpedoes-corn oil inside and out," are preferred by rats to "whole wheat torpedoes-corn oil inside and out."

Rats prefer raw linseed oil to corn oil.

The Lihue practice was changed to "rolled barley-raw linseed oil outside."

Where either corn oil or raw linseed oil is outside only, wheat torpedoes tend to be more attractive to rats than barley torpedoes but where either oil is inside and out, barley is much preferred to wheat.

"Rolled barley-raw linseed oil inside and out" is preferred by rats to both "rolled barley-corn oil inside and out" and "rolled barley-raw linseed oil outside only."

"Rolled barley-cocoanut oil outside only" is equally as attractive to rats as

"rolled barley-raw linseed oil outside only." Cocoanut oil is less expensive.

"Rolled barley-cocoanut oil inside and out" is greatly preferred by rats to "rolled barley-cocoanut oil outside only."

"Rolled barley-cocoanut oil inside-raw linseed oil outside" is preferred by rats to both "rolled barley-cocoanut oil inside and out," and to "rolled barley-raw linseed oil inside-cocoanut oil outside."

The plantation practice was changed to "rolled barley-cocoanut oil inside-raw linseed oil outside."

"Rolled oats-cocoanut oil inside-raw linseed oil outside" is preferred by rats to "rolled barley cocoanut oil inside-raw linseed oil outside."

A mixture of "5 parts of rolled barley-2 parts of rolled oats-cocoanut oil inside-raw linseed oil outside" is nearly as attractive to rats as "rolled oats alone-cocoanut oil inside-raw linseed oil outside." These two baits are outstanding and so nearly the same in rat acceptance that effectiveness per unit cost must be the deciding factor.

Under the conditions of field 30 M, the "barley(5)-oats(2) mixture-cocoanut oil inside-raw linseed oil outside" proved superior to various meat baits prepared by Garlough.

Hot paraffin passes through oil-impregnated wrapping tissue. Where raw linseed oil coats the grain, the paraffin adheres to the grain; but where cocoanut oil coats the grain the paraffin does not adhere, but flakes off. The entrance into a torpedo of hot paraffin can be reduced to a minimum by limiting the inside oil to one pint to 5 pounds of grain (rolled barley) and by using 3 sheets of wrapping tissue per torpedo. The use of an inexpensive but strong wax paper may be the solution to this problem.

The coating of grain with oil does not alter the killing effectiveness of the poisoned grain.

The efficiency of the newer baits can only reach a maximum by increasing the thallium sulphate concentration to about one pound per 100 pounds of grain. A quarter of a torpedo would then be a lethal dose for any rat, and fair-sized nibbles would kill small-sized rats and mice. Because of the high cost of thallium sulphate the increase in kill may not be large enough to offset the additional cost. Whether or not the additional thallium sulphate would have any effect on the attractiveness of the bait remains to be determined.

Effective take per unit cost of the better baits is being investigated. The bait which gives the greatest kill per dollar will be adopted as a standard at Lihue.

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(1) The travelling agent of Death, 1931. (Specially prepared for the Convention and Exhibit of the American Public Health Association.)

(2) Barnum, C. C., 1931. Rat control in Hawaii. The Hawaiian Planters' Record, Vol. XXXIV, p. 423.

(3) Doty, R. E., 1932. The use of corn oil for thallium wheat torpedoes. The Hawaiian Planters' Record, Vol. XXXVI, pp. 117-125.

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Yams for Hawaiian Gardens

By E. L. Caum and J. P. Martin

In the spring of 1935 several tubers of an unidentified Oriental yam were obtained from the Philippines by Dr. H. L. Lyon. To check its value as an accessory food crop for the plantations, and also to permit its identification, plantings were made at the Pathology Plot of the Experiment Station. It proved to be the Spiny yam or, as it is known in the Straits Settlements, the Lesser yam, *Dioscorea esculenta.* The plant is a native of some part of the eastern Asiatic region, occurring in the wild in India, Malaya, the Philippines and Guam, although there is no definite evidence as to just where the species actually originated. The tubers of this yam are of considerable economic importance as a food crop, and as a result the plant has been transported far and wide throughout the Asiatic tropics. It has not, however, attained the range of another important Asiatic yam, *Dioscorea alata,* the Winged or Greater yam, which is now cultivated throughout the tropics the world around.

As a natural result of its wide distribution and long cultivation, the Spiny yam is distinctly variable in a number of characters, such as size, shape and flavor of the tubers, the size of the leaves, the degree of spininess of the stems and roots and the ability to produce flowers and seeds. This variability and spontaneous occurrence in many places are reflected in the multiplicity of names, both vernacular and technical, by which the plant is known.

The earliest reference to this yam that we have found is in Vol. 5 of Rumphius' *Herbarium Amboinense* (1750) where, on pages 357-359, under the name Combili or Combilium, three varieties are discussed at length in Latin and Dutch, and illustrated with a full-page plate, Tab. 126, which is here reproduced as Fig. 1. The first technical description of the species was published in 1790 when Loureiro in his *Flora Cochinchinensis* named it *Oncus esculentus.* Later authors recognized the plant as a species of Dioscorea, but apparently did not recognize the identity of their specimens with the *Oncus esculentus* of Loureiro. Thus throughout the literature we find the plant described many times under many names, by Roxburgh three times, as *Dioscorea aculeata, D. fasciculata* and *D. spinosa,* by Kunth as *D. tiliaefolia,* by Hemsley as *D. cymosula,* by Balfour as *D. lanata,* by Blanco as *D. sativa* and *D. tugai,* to list only a few. The identity of the plants to which these names were applied with the one described by Loureiro was recognized by Burkill in an article in *The Gardens' Bulletin of the Straits Settlements,* Vol. 1 (1917) pp. 396-399. The correct scientific name thus becomes *Dioscorea esculenta* (Loureiro) Burkill.

The plant is a twining vine, growing to a length of probably 20 to 30 feet in the usual crop period of 8 to 9 months. The stems are round in cross-section, slightly tomentose, especially on the young growth, and armed, particularly near the base, with small sharp thorns. There are always two larger hooked spines at the base of each leaf stalk. The leaves are heart-shaped, up to six inches in diameter or even more, with prominent veins (Fig. 2). The flowers are green, about one-sixth inch in diameter, and are borne in long slender drooping spikes which arise, usually singly,

in the axils of the leaves. Flowers are rarely formed, however, male flowers even more rarely than female. The tubers are predominately roughly cylindrical to spindle- or carrot-shaped with an appreciable percentage of lobed or toed forms, and covered with many very short rather stiff fibrous rootlets (Fig. 3). The flesh is white, the thin skin light brown. From the base of the stem there arise three classes or categories of underground organs (Fig. 4). First there are the smooth rather heavy cord-like structures of various lengths, on the ends of which the tubers are formed. These tend to extend straight out or slightly upward, and the tubers themselves frequently point upward so that they, or at least their free ends, lie very near the surface of the ground. It is for this reason that, in cultivation, the plants are hilled up. The second class of organs arising from the common center are the feeding roots, long, slender and sparsely branched. Last, but by no means least, are the protective organs. These, possibly modified feeding roots, are rather heavy stiff structures bearing formidable spines often an inch in length (Figs. 4 and 5). They form a veritable barbed wire entanglement around the feeding roots and some of the tubers, and furnish the incentive for the name, the "Barbed Wire yam," which the plant has acquired at the Experiment Station. It is difficult to see just what the significance of these thorny structures may be, as they are not sufficiently long to enclose all the tubers, most of which lie well beyond their protection. In fact the tubers, lying close to the surface of the soil, seem to invite the attention of pigs. The main function which might be ascribed to the underground thorns is to interfere with the human harvesting of the crop. Despite the necessity of contending with these spikes the yam is extensively cultivated throughout the Oriental tropics, and in areas where the plant grows spontaneously, tubers of the wild plants are dug and gathered in the jungle.

The tubers furnished by Dr. Lyon were used for planting material, and on April 10, 1935, twenty-two cuttings were planted in two rows at the Pathology Plot, the rows and the cuttings spaced approximately two feet apart. The preparation of the seed pieces is simple, the yam tubers being handled exactly like the tubers of the ordinary white potato. In common with the fleshy storage roots or underground branches of many other plants, the yams have the faculty of developing adventitious buds at almost any point on the exterior. Six of the cuttings failed to grow, and the sixteen vines resulting from the others were trained over a rough bamboo trellis (Fig. 6), and the plants hilled up during their growth. After nine months, (on January 9, 1936, to be exact), when the leaves had begun to turn yellow and fall, the vines were torn down and the tubers harvested. No fertilizer was applied, as no symptoms of plant food deficiency were noted at any time during the growth of the vines. The tubers obtained from these plants varied greatly in size and shape, ranging upwards from tiny nubbins about the size of a marble. The largest one, shown in Fig. 7, weighed four pounds. The normal type were from 8 to 10 inches in length and 6 to 8 inches in circumference, with a weight of about 1½ to 2 pounds, which seems to be about the average size for tubers of this species. The total yield from the sixteen hills (Fig. 8) weighed 151 pounds.

In the article by Burkill, previously referred to, the tubers of a number of races from India, Indo-china and the Philippines are described and illustrated, but the

particular form which we have here does not seem to be among those discussed. At least, the tubers of our plant do not correspond especially well with any of those figured, although they resemble Burkill's number 276, a Philippine race, more closely than any of the others.

We are not in position to say much about the preparation of the yams for the table, except that they should be peeled and boiled for twenty minutes or so, to remove a crystalline substance similar to the calcium oxalate in taro, and a bitter principle that is sometimes present. After boiling they may be served direct, or baked if desired. According to the members of the Experiment Station staff who have sampled them, the yams are decidedly palatable, and there was some slight difficulty experienced in preventing the Filipino helpers at the Station from making away with the entire crop. There is apparently no reference to methods of preparation of these vegetables in any of the literature available.

In a survey of the markets in Honolulu we have found four kinds of locally grown yams offered for sale (Figs. 9-12) and one kind imported from China (Fig. 13). At least one other Chinese variety has been seen in the past, but no tubers were found in the markets at this time. In addition to these true yams, locally grown tubers of the Yam Bean, *Pachyrrhizus erosus* (Fig. 14) are sold as yams, and the heavy tuberous roots of an unidentified plant, possibly a Composite (Fig. 15), are imported as yams from China. Tubers of the Spiny yam were not found in the markets.

Shortly after this market survey, we received as a gift from the Bishop Museum a single tuber (Fig. 16) of a giant yam that was brought to Honolulu from Fiji. This tuber weighed 31 pounds. It is probably the same variety that is grown throughout southern and southeastern Polynesia, where it is said to produce tubers up to 50 pounds or even more in weight.

Further plantings of the Spiny yams will be made, as well as of the other varieties which we now have or which may later be obtained, in order to obtain sufficient planting material to supply any of the plantations that may wish to make an undoubtedly popular addition to their vegetable gardens; more particularly those connected with the Filipino camps.

Fig. 1. The Spiny yam, from the *Herbarium Amboinense.*

Fig. 2. The leaves and stem of the Spiny yam, showing the hooked spines at the base of the petioles.

Fig. 3. Tubers of the Spiny yam.

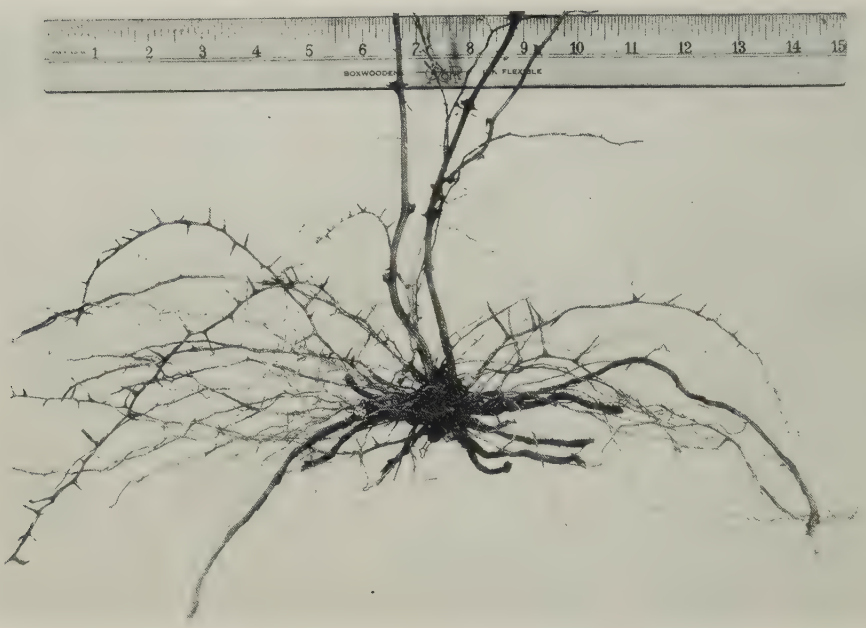

Fig. 4. The base of the stem and the underground parts of the plant, showing the stubs of the tuber stalks, the feeding roots and the protective roots.

Fig. 5. Several of the protective roots, detached from the plant.

Fig. 6. The vines at the Pathology Plot, just before harvesting.

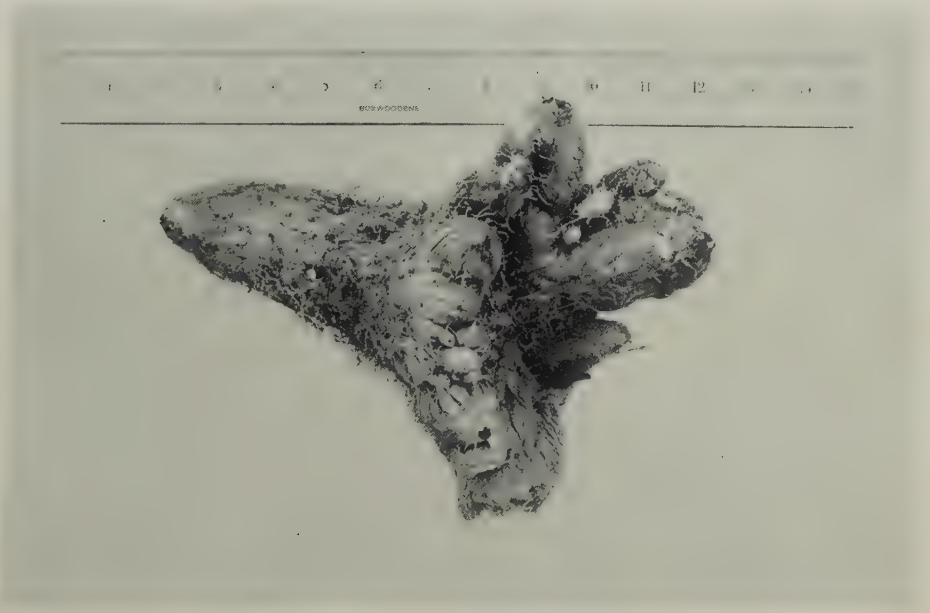

Fig. 7. The largest single tuber in the crop.

Fig. 8. One hundred and fifty-one pounds of yams from sixteen vines. The measure is a meter stick, 39⅓ inches.

Fig. 9. The tuber of a locally grown species of yam, from the market.

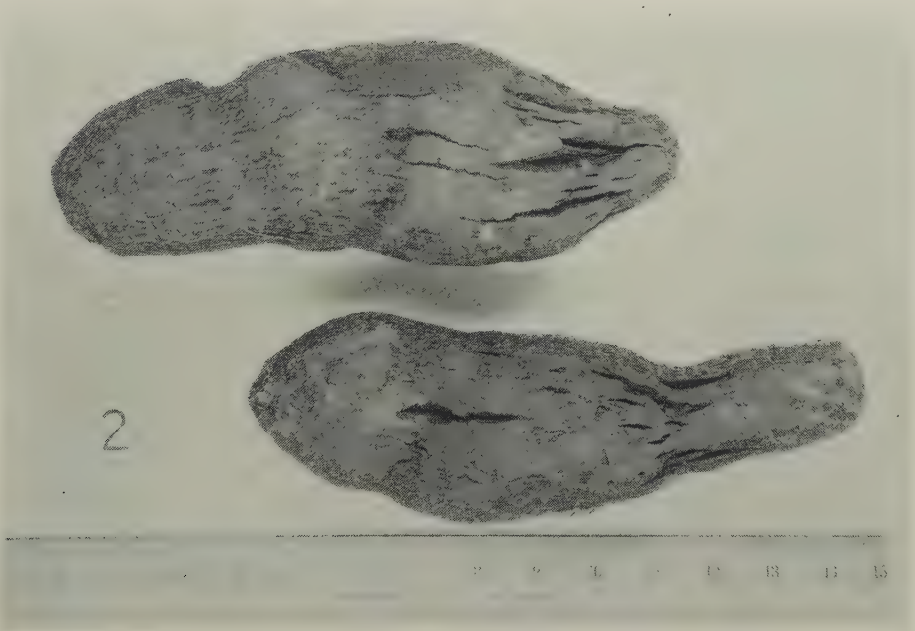

Fig. 10. Tubers of a locally grown species of yam, from the market.

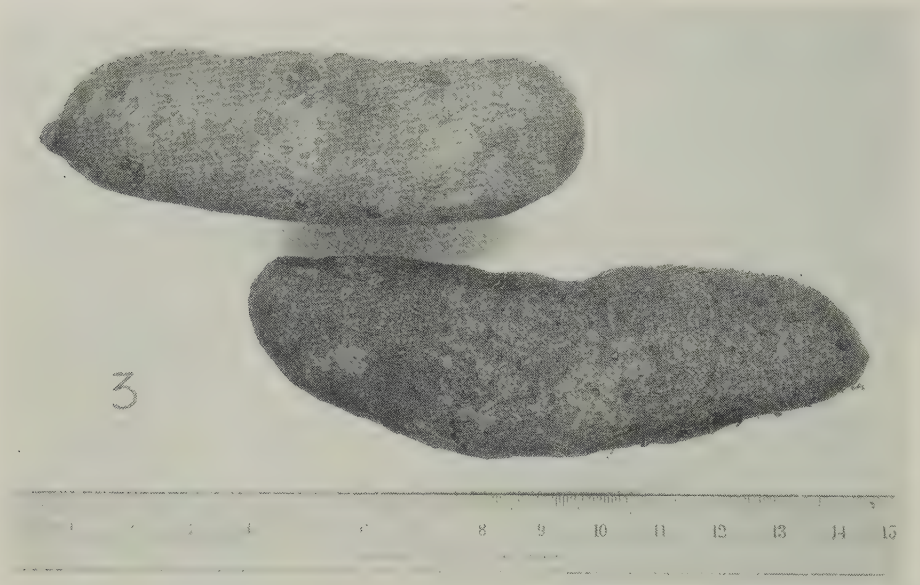

Fig. 11. Tubers of a locally grown species of yam, from the market.

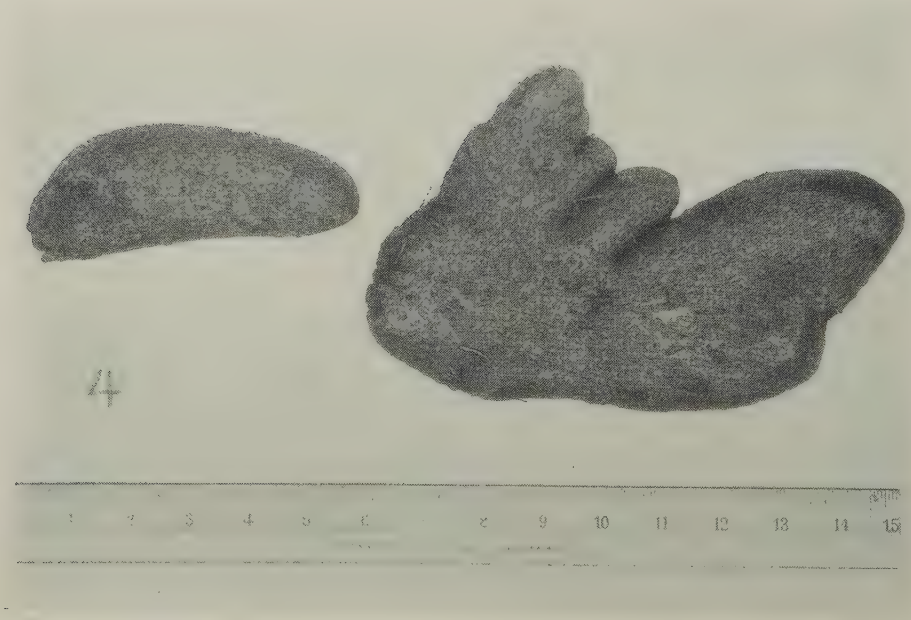

Fig. 12. Tubers of a locally grown species of yam, from the market.

Fig. 13. Tubers of a species of yam imported from China, from the market.

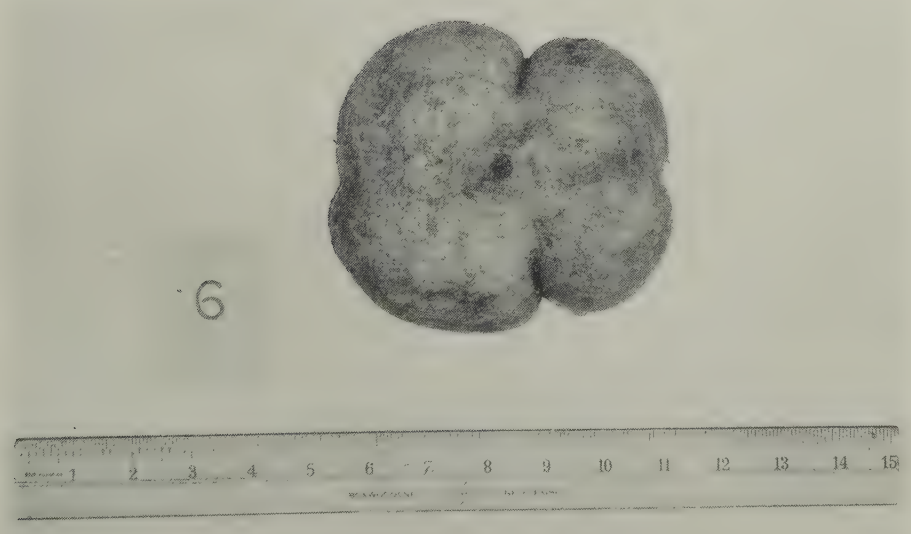

Fig. 14. The tuber of the Yam Bean, from the market.

Fig. 15. Tuberous roots of an unidentified Chinese plant, sold as yams, from the market.

Fig. 16. A tuber of a giant Fijian yam.

Primary and Total Combustion Volume in Factory Boilers

The committee, consisting of G. H. W. Barnhart, R. B. Johnson and R. H. Lloyd, appointed at the 1932 Annual Meeting of the Association of Hawaiian Sugar Technologists for defining combustion volume measurements, gave us the following definitions which we have requested be followed in reporting combustion volume in the Synopsis schedules.

Primary Combustion Volume: Include the cubical contents of the furnace immediately above the fuel bed, assuming that the fuel bed covers the grates and adjacent shelves (where installed) or the floor in case of a Cook furnace.

Total Combustion Volume: Include the cubical contents of the furnace between the grate, or floor in case of a Cook furnace, and the first place of entry into or between the tubes as indicated by any one of sketches Nos. 1 to 7, pages 159 to 161, of the 1932 Report of Association of Hawaiian Sugar Technologists.

The spaces reported should be those intended for combustion of bagasse. If whole or parts of furnaces are intended for oil burning, such space should be reported separately. An illustration of this distinction is given in Fig. 7, page 161, of the 1932 Report noted above.

SUGAR TECHNOLOGY DEPARTMENT.
W. L. M.

Mill Roller Openings

The report of the committee on Mill Opening Measurements of the Association of Hawaiian Sugar Technologists to recommend a standard method of expressing mill openings for use in the Annual Synopsis was presented by A. S. Taylor at the 1934 Annual Meeting of the Technologists and adopted October 23, 1934. We have requested that the recommendations be followed in preparing Synopsis schedules. Their report and examples follow:

Your committee appointed to recommend a standard method for expressing mill openings begs to report as follows:

Measurement referred to hereafter shall be the dimension from the tip to the bottom of the groove, representing the vertical distance between these points.

We recommend that mill opening be expressed in the following form:

T (O) B

when:

T = Distance from tip to bottom of groove of top roller.

B = Distance from tip to bottom of groove of bottom roller.

O = Vertical distance, plus or minus, from tips of respective rollers. A minus dimension shall indicate that the rollers are in mesh and overlap. When "O" is plus, this is the actual measurement between tips of the top and bottom roller, measured vertically.

Examples:

1. When the grooves are ¾" deep in both top and bottom rollers, and the tips are ¼" apart, the opening would be written:

¾" (+¼") ¾"

2. When the grooves are ¾″ deep in both rollers, and the tips of both rollers are exactly in line, the opening would be written:

   ¾″ (o) ¾″

3. When the grooves are ¾″ deep in both rollers, and the tips overlap ¼″, the opening would be written:

   ¾″ (—¼″) ¾″

4. When the grooves are ¾″ deep in both rollers, and the rollers are set iron to iron, the opening would be written:

   ¾″ (—¾″) ¾″

5. When the grooves are ⅜″ in the top, and ¾″ in the bottom roller, and the distance between tips is ¼″, the opening would be written as follows:

   ⅜″ (+¼″) ¾″

6. Under the conditions of 5, but with the grooves meshing and set iron to iron (assuming perfect matching of grooves) the opening would be written:

   ⅜″ (—⅜″) ¾″

SUGAR TECHNOLOGY DEPARTMENT.
W. L. M.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 30, 1935, TO MARCH 11, 1936.

Date	Per Pound	Per Ton	Remarks
Dec. 30, 1935	3.25¢	$65.00	Puerto Ricos.
" 31	3.28	65.60	Cubas.
Jan. 7	3.10	62.00	Cubas or duty frees.
" 8	3.20	64.00	Puerto Ricos.
" 9	3.15	63.00	Philippines.
" 13	3.20	64.00	Cubas, Puerto Ricos.
" 14	3.19	63.80	Cubas, 3.18, 3.20.
" 16	3.20	64.00	Cubas.
" 17	3.235	64.70	Cubas, 3.22, 3.25; Puerto Ricos, 3.25.
" 18	3.275	65.50	Cubas, 3.25; Philippines, 3.30.
" 20	3.325	66.50	Cubas, 3.32; Puerto Ricos, 3.33.
" 24	3.35	67.00	Puerto Ricos.
" 27	3.38	67.60	Cubas.
" 29	3.35	67.00	Puerto Ricos.
Feb. 5	3.30	66.00	Puerto Ricos.
" 14	3.31	66.20	Puerto Ricos, 3.30, 3.32.
" 15	3.30	66.00	Puerto Ricos.
" 18	3.35	67.00	Puerto Ricos.
" 21	3.39	67.80	Puerto Ricos, 3.38; Philippines, 3.38, 3.40.
" 24	3.40	68.00	Puerto Ricos.
" 28	3.45	69.00	Philippines, Puerto Ricos.
Mar. 4	3.49	69.80	Cubas.
" 5	3.50	70.00	Cubas.
" 6	3.5367	70.73	Puerto Ricos, 3.50, 3.55; Cubas, 3.56.
" 11	3.51	70.20	Cubas.